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The *American Journal of Alternative Agriculture* provides an international forum for original research and review articles on the biological, physical, social science, and policy aspects of alternative agriculture and food systems, focusing on the effective use of renewable resources and biodiversity in agro-ecosystems. The journal particularly welcomes multidisciplinary, holistic, systems research that addresses the multiple challenge of economically meeting basic human needs for food, fiber, and energy while maintaining essential natural and environmental resources.

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AMERICAN JOURNAL OF ALTERNATIVE AGRICULTURE

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An economic comparison of organic and conventional grain crops in a long-term agroecological research (LTAR) site in Iowa

Kathleen Delate, Michael Duffy, Craig Chase, Ann Holste, Heather Friedrich, and Noreen Wantate

Abstract. *Based on the interest of organic and conventional farmers in Iowa in long-term analysis of organic systems, the Neely–Kinyon Long-Term Agroecological Research (LTAR) site was established in 1998 to examine the agronomic and economic performance of conventional and organic systems, using certified organic production practices. We report the results of the economic analysis from 3 years of production (1999–2001). Using organic price premiums for organic crops, returns for corn within the organic corn–soybean–oat and corn–soybean–oat–alfalfa rotations were significantly greater than conventional corn–soybean rotation returns (US$126 ha^{-1}). Corn returns were not significantly different between the two organic rotations, at US$655 ha^{-1} and US$674 ha^{-1}, respectively. Returns for soybean within the organic corn–soybean–oat and corn–soybean–oat–alfalfa rotations were not significantly different, at US$1233 ha^{-1} and US$1326 ha^{-1}, respectively. Organic soybean returns were significantly greater than conventional soybean crop returns (US$235 ha^{-1}) in the corn–soybean rotation. Rotational 3-year average returns were US$180 ha^{-1} for the conventional corn–soybean rotation, compared to US$734 ha^{-1} for the organic corn–soybean–oat and US$739 ha^{-1} for the organic corn–soybean–oat–alfalfa rotation.*

Key words: agricultural profitability, conventional rotations, economic returns, labor requirements, organic rotations, production cost comparisons

Introduction

Sales of organic products were US$8 billion in the US in 2001, continuing a 20% annual growth rate (Greene, 2000; OTA, 2001). The most recent US census in 1994 identified 4050 organic farmers on 600,000 ha. The Organic Farming Research Foundation placed the number of organic farmers at 10,000 in 1997 (Walz, 1999). In 1999, Iowa farmers reported 48,600 ha of organic production in the Iowa Department of Agriculture and Land Stewardship survey (IDALS, 2000), with many hectares believed to be unreported. This increase represents a doubling in organic production from the previous year, and a sixfold increase from 1996.

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European consumers have led the demand for organic products, particularly in The Netherlands and Scandinavia, with the world market value of organic products at US$45 billion (Lampkin and Padel, 1994). While the desire for genetically modified (GM)-free foods has contributed to this increase in organic food consumption, consumers also perceive health benefits from organic foods (Wilkins and Hillers, 1994), with 90% of US citizens willing to consider including organic foods in their diets (Hartman Group, 2001).

Economic sustainability of organic systems

The majority of economic studies of organic systems across the US describe a viable system without government support and premium prices (Delate, 2002). In an analysis of economic discrepancies between organic and conventional systems in the literature, the most acute differences occurred when conventional systems were compared to organic systems with unprofitable crop rotations or inadequate management. When soybean [*Glycine max* (L.) Merr.], the most lucrative organic crop in the Corn Belt, was omitted from an organic rotation, for example, the economic comparison between organic and conventional returns was

skewed in favor of the conventional C–S [corn (*Zea mays* L.)–soybean] rotation (Chase and Duffy, 1991).

In a more typical organic rotation that included soybean, in South Dakota, organic soybean costs of production were similar to conventional costs, but organic premiums were not calculated in the returns (Dobbs and Smolik, 1996). In Pennsylvania, costs of production were 12% lower in the organic system across all rotations (Hanson et al., 1997), but organic premiums were also not calculated. In California, organic tomato (*Lycopersicon esculentum* Mill.) production costs were 5% higher than conventional costs, but with organic premiums, the organic returns were superior (Clark et al., 1999). Reganold et al. (2001) also demonstrated organic apple (*Malus* sp.) production systems with improved profits. Because certified organic farmers obtain organic price premiums for their crops whenever possible, these should be included to fully account for potential economic benefits (Welsh, 1999). In one of the few economic analyses of conventional and organic grains where organic premium prices were calculated, returns from the organic rotations exceeded that of the conventional corn–soybean rotation (Olson and Mahoney, 1999).

Long-Term Agroecological Research (LTAR) in Iowa

In 1998, the Leopold Center for Sustainable Agriculture identified the need for dedicated lands throughout Iowa where research on organic practices could be conducted over the long term (Delate and DeWitt, 1999). The Neely–Kinyon (N–K) Long-Term Agroecological Research (LTAR) site was established in 1998 in Greenfield, Iowa, to examine the agronomic and economic performance of conventional and organic systems, using required practices for certified organic production (Delate and Cambardella, 1999, 2000, 2001, 2002). After meeting with focus groups and the N–K Farm Association, we developed an experimental design to evaluate typical crop rotations in the surrounding area (Delate, 2002). We report here the results of the economic analysis from 3 years of production (1999–2001).

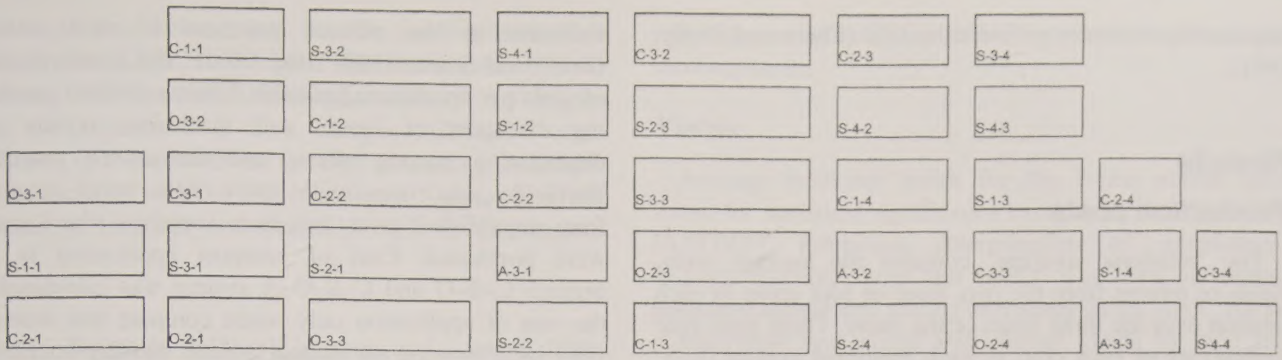
Materials and Methods

The Neely–Kinyon Farm Association dedicated a 7-ha block of the Iowa State University (ISU) Neely–Kinyon Research Farm for this long-term study. One conventional rotation and three organic rotations were established in the LTAR experiment in a completely randomized design. Four replications of each crop from each rotation were planted each year. Treatments included: (1) conventional corn–soybean (C–S); (2) organic corn–soybean–oat (*Avena sativa* L.)/alfalfa (*Medicago sativa* L.) (C–S–O); (3) organic corn–soybean–oat/alfalfa–alfalfa (C–S–O–A); and (4) organic soybean–winter rye (*Secale cereale* L.) (S–R) (Fig. 1). The final rotation was permitted in certified organic fields when the experiment was initiated, but disallowed in 2000, due to new restrictions requiring a minimal full-year of alternative crops (IDALS, 2000). Thus, we did not analyze for this rotation in this study. Rye was used as a cover crop in the other two organic rotations (C–S–O and C–S–O–A), however, because rye provides natural allelopathic chemicals that mitigate weed seed establishment in organic soybean production. Following harvest of all organic corn plots, winter rye was no-till drilled at a rate of 62.7 kg ha^{-1} as a standard organic farming practice. In the second rotation (C–S–O), oat was underseeded with alfalfa and the oat grain crop was harvested. In the third rotation (C–S–O–A), fields were managed in a similar manner as the second rotation in the first year, but in the second year, alfalfa was harvested 1–3 times, depending on weather and plant growth.

Crops were grown on 0.1–ha plots using farm-size equipment and normal area farming practices. Crop variety selection and planting methods followed the recommendations of the Neely–Kinyon Farm Association, which included the most suitable corn, soybean, oat and alfalfa hybrid varieties for the area. Corn varieties grown in both the conventional and organic fields included 'Wilson 1790W' in 1999 (a white milling corn variety), and 'Pioneer 34W67' (a yellow feed corn variety) in 2000 and 2001. Corn was planted 4.5 cm deep at a rate of 68,000–80,000 kernels ha^{-1} over the course of the experiment. Soybean varieties grown in both the conventional and organic fields were 'IA 2034' in 1999, 'Pioneer 9305' in 2000 and 'Northrup-King 2412' in 2001. All varieties were clear-hilum soybean for the tofu market. Soybean seeds were planted in 76-cm rows, at a depth of 5 cm, in organic and conventional plots at a rate of 400,000–500,000 seeds ha^{-1} over the course of the experiment. Untreated seed was used in the organic fields, per certification requirements.

Harvesting was done within the normal period for each crop, using standard farm equipment, such as combines and hay rakes for alfalfa. A hay crop of alfalfa, fescue (*Festuca rubra* L.) and oat, seeded in 1998 in the 10-m border strips around each plot and around the perimeter of the experiment, was periodically mowed and maintained as the required buffer between conventional and organic production, per certification standards.

Conventional corn fields were fertilized with 28% urea at 135 kg ha^{-1} of nitrogen (N) following Iowa State University (ISU) recommendations. Organic corn fields received locally produced swine hoop-house compost in the spring of each year from the ISU Armstrong Research and Demonstration Farm. The compost consisted of deep-bedded swine manure mixed with corn stalks and straw, and averaged 1.54, 0.65 and 3.06% N–P–K. Using cornstalk nitrate results from the previous year to guide application rates, the goal of the organic corn fertilization program was to apply the same amount of N (135 kg ha^{-1}) as to the conventional fields, based on total N in compost



Each plot is approximately 0.1 ha (45 x 23 m).
All alleys are 10 m wide.

There is a total of 40 plots with four replications of each crop in each rotation-treatment.

Rotation	Plots/rotation	Sequence
1	8	Conventional C (corn)–S (soybean) rotation
2	12	Organic C–S–O (oat); oat underseeded with alfalfa (alfalfa grown for 1 year)
3	16	Organic C–S–O–A (alfalfa) oat underseeded with alfalfa (alfalfa grown for 2 years)
4	4	Organic S–R (rye); rye as a winter cover crop (plots not used in economic analysis)

Coding: crop; rotation; replicate. **Example:** C–1–1 = conventional corn in rotation 1 (C–S), the first replicate plot.

Figure 1. Long-Term Agroecological Research (LTAR) plot map at the Neely–Kinyon Farm.

applications. Because of the slower release of N from compost, however, the actual amount of N used by the organic crop was lower than the application rate.

Weeds were managed in the organic corn and soybean fields through cultivation; in addition, the fall-planted rye cover was disked under the following spring to assist in soybean weed management. Large weeds above the soybean canopy were hand-pulled in a continuous movement across soybean fields ('soybean walking') to remove any potentially staining weeds that would reduce the market value of the clear-hilum varieties destined for the tofu market.

The predominant costs in the conventional system were associated with herbicide inputs. As an example, the herbicide program for conventional corn and soybean in 2000 included the following practices*: Harness® (acetochlor) at 2.0 kg ha^{-1} and Atrazine® (atrazine) at 1.12 kg ha^{-1} were applied to conventional corn plots on 24 April 2000. Conventional corn plots received Buctril® (broxynil) (0.28 kg ha^{-1}), Accent® (nicosulfuron) (0.004 kg ha^{-1}), and the spreader additives, ammonium sulfate (1.4 kg ha^{-1}) and nonionic surfactant (29.2 l ha^{-1}), on 25 May. Prowl® (pendimethalin) was applied at 1.4 kg ha^{-1} on 16 May 2000, to conventional soybean plots, and Galaxy® [bentazon (0.84 kg ha^{-1}) + acifluorfen (0.19 kg ha^{-1})], Prestige® (sethoxydin) at 0.28 kg ha^{-1}, and the additives, crop oil concentrate and ammonium sulfate (1.4 kg ha^{-1} each), were applied on 14 June. Corn rootworm control was not warranted from 1999 to 2001, based on sampling.

Field operations and hours

Pre-plant tillage consisted of a field cultivator in the conventional corn rotation and a disk in the soybean rotation (Table 1). Fertilizer and compost were applied in the spring. Pre-emergence and post-emergence pesticide applications were made each year. Post-emergent mechanical weed control using a row cultivator was common, per local conventional practices.

Corn operations were identical in the organic rotations. The primary tillage implement following alfalfa was a moldboard plow followed by a tandem disk and field cultivator. Alfalfa and surface-applied compost were incorporated simultaneously with moldboard plowing prior to annual corn crops in the organic fields. Post-emergent mechanical weed control consisted of a harrow, rotary hoe, row cultivator and propane flame cultivator. Corn stalks were disked and rye planted in the organic rotations following corn harvest in September–October.

The organic soybean weed-management program began with disking and field cultivating rye prior to soybean planting. Post-emergent weed control consisted of rotary hoeing, row cultivating and 'walking' in the organic fields. Alfalfa was seeded with the oat crop for both organic rotations. The choice and timing of all cultural practices were decided through recommendations of area organic farmers and by the research farm manager. All labor requirements, excluding hand labor, were estimated from

*All herbicides listed are active ingredient.

engineering estimates provided by ISU (Chase and Duffy, 1991).

Results

Production costs

The 'rotational average' contains the average costs, yields or returns from the two, three or four crops in each rotation over the three years of the study. There were four replications of each crop in each rotational system (C–S; C–S–O; C–S–O–A) grown each year, for a total of 36 observations per year. In the conventional C–S rotation, less fieldwork (4.62 h ha^{-1}) was required, compared to the organic rotations (Table 2). The conventional soybean crop included 4.94 h of hand labor per hectare per year because we also walked through the conventional food-grade soybean and removed large weeds above the canopy, which is a normal practice for this crop. The organic C–S–O and C–S–O–A rotations incurred 6.42 h ha^{-1} and 5.88 h ha^{-1}, respectively. Within each of the organic rotations, corn and soybean required the most hours to grow and harvest crops. The application of compost at 26.9 Mg ha^{-1} over 3 years, and mechanical weed control for corn, contributed a vast majority of the fieldwork time needed, whereas hand labor (4.94 h ha^{-1}) and mechanical weed control contributed to the soybean hours.

Machinery (fixed and operating costs) and input costs of production were determined by applying standardized cost estimates to the cultural practices in each rotation (Duffy and Smith, 1999, 2000, 2001). The standardization of costs per operation eliminates differences from purchasing discounts of inputs and machinery repairs and depreciation, among others, and focuses on practices. Herbicide and insecticide price data were obtained from unpublished price lists from suppliers where inputs were purchased. Cost of compost application in the organic C–S–O and C–S–O–A system was calculated as the cost of application only, since compost was received from local sources, per normal organic farming operations in the area of the study.

Total production costs for the corn in the conventional rotation were substantially higher (31%) than the organic rotations (US$489 for C–S versus US$336 for both C–S–O and C–S–O–A) (Table 3). The organic rotations did not incur any pesticide or conventional fertilizer costs, but did incur higher machinery costs as pest management was handled mechanically. Seed expense was higher in the organic rotations due to higher seeding rates.

Total production costs for soybean in the conventional rotation were higher (11%) than the organic rotations (US$316 for C–S versus US$282 for C–S–O and C–S–O–A) (Table 3). The major contributing factor was the cost of chemical versus mechanical weed control between the conventional and organic rotations. Seed expense was higher in the organic rotations, however, due to the seeding of rye following corn prior to soybean planting, which is considered a soybean production cost.

Table 1. Field operations by rotation.[1]

	Conventional, C–S		Organic, C–S–O			Organic, C–S–O–A			
Operation	**Corn**	**Soybean**	**Corn**	**Soybean**	**Oat**	**Corn**	**Soybean**	**Oat**	**Alfalfa**
Fertilizer (N)	x								
Fertilizer (compost)			3x		x	3x		x	
Fall, disk stalks				x			x		
Fall, plant rye				x			x		
Disk rye				2x			2x		
Plowed (moldboard)			x			x			
Tandem disk		x	x			x			
Harrow									
Spray	x								
Field cultivate	x		x	x	x	x	x	x	
Plant/drill	x	x	x	x	x	x	x	x	
Cultipack[2]					x			x	
Spray	x	x							
Harrow			x	x		x	x		
Row cultivate	x		3x	3x		3x	3x		
Rotary hoe		x	x	x		x	x		
Flame cultivation			x			x			
Harvest[3]	x	x	x	x	x	x	x	x	x

[1] Operations varied among years. Operations listed are those typically performed.

[2] This implement consists of roller bars that compress soil over the oat and alfalfa seed to improve seed-to-soil contact.

[3] Corn (C), soybean (S) and oat (O) were harvested with a combine, whereas alfalfa (A) was harvested by a mower, then raked and baled. Oat straw was raked and baled. Alfalfa was harvested three times.

Average production costs for the conventional C–S rotation were US$82 ha^{-1} higher than the organic C–S–O rotation (US$403 versus US$321) and US$119 ha^{-1} higher than the organic C–S–O–A rotation (US$403 versus US$284). In these rotations, the cost of seeding the alfalfa crop is included with the cost of oat seed. Savings from the absence of fertilizer and pesticide costs in the organic rotations were greater than overall increased machinery and seed expenses.

Table 2. Estimated fieldwork by crop and rotation, 1999–2001.[1]

Rotation/Crop	Fieldwork (h ha^{-1})
Corn–soybean (conventional)	
Corn	2.10
Soybean	7.11
Average	4.62
Corn–soybean–oat (organic)	
Corn	6.45
Soybean	8.89
Oat	3.95
Average	6.42
Corn–soybean–oat–alfalfa (organic)	
Corn	6.45
Soybean	8.89
Oat	3.95
Alfalfa	4.20
Average	5.88

[1] Based on Duffy and Smith (1999, 2000, 2001).

Yields

Average treatment yields for the 3-year period were tested for statistical significance using analysis of variance (ANOVA). Following determination of significance, Tukey's multiple range test (HSD) was used for testing statistical differences among individual crops (SAS, 1988).

Individual year yields and average yields by crop and rotation are reported in Table 4. All crops were grown every year; thus the averages cover the entire 3-year period. Variation in weather, varieties and other conditions did affect the variability in yields from year to year. The differences among rotations, however, remained relatively stable and statistically equivalent. The conventional C–S average corn yield of 8654 kg ha^{-1} was not significantly higher than the organic C–S–O average corn yield of 8152 kg ha^{-1} or the organic C–S–O–A yield of 8340 kg ha^{-1}. Soybean yield averages ranged from 2755 (C–S–O) to 2956 kg ha^{-1} (C–S–O–A), while conventional soybean yielded 2889 kg ha^{-1}. Oat yield ranged from 2691 (C–S–O–A) to 2799 kg ha^{-1} (C–S–O). Alfalfa yield averaged 2.6 Mg ha^{-1} over the 3-year period.

Returns

The analysis of returns is divided into returns to land, labor and management; and an analysis conducted with a labor charge subtracted to estimate a return to land and

Table 3. Annual production costs (US$ ha^{-1}) by crop and rotation, 1999–2001.[1]

Rotation	Corn	Soybean	Oat	Alfalfa	Average[2]
Corn–soybean (conventional)					
Machinery	158	104			131
Seed	72	74			74
Chemical	153	99			124
Fertilizer	54	0			27
Miscellaneous	52	40			47
Total	489	316			403
Corn–soybean–oat (organic)					
Machinery	220	158	165		180
Seed	77	89	165		111
Chemical	0	0	0		0
Fertilizer	0	0	0		0
Miscellaneous	40	35	15		30
Total	336	282	346		321
Corn–soybean–oat–alfalfa (organic)					
Machinery	220	158	161	161	175
Seed	77	89	165	0	84
Chemical	0	0	0	0	0
Fertilizer	0	0	0	0	0
Miscellaneous	40	35	15	15	27
Total	336	282	341	175	284

[1] Corn machinery expenses include field operations, drying, handling and hauling. Machinery expenses for all other crops include field operations, handling and hauling. Land and labor costs are not included.
[2] Totals rounded to the nearest dollar.

Table 4. Yields by crop and rotation, 1999–2001.[1]

Rotation/Crop	1999	2000	2001	Average 1999–2001
Corn–soybean (conventional)				
Corn	10096	8842	7024	8654
Soybean	3225	2688	2688	2889
Corn–soybean–oat (organic)				
Corn	7651	8842	8027	8152
Soybean	3024	2419	2889	2755
Oat	3193	2260	2906	2799
Corn–soybean–oat–alfalfa (organic)				
Corn	7525	9281	8215	8340
Soybean	3225	2486	3158	2956
Oat	2906	2189	2978	2691
Alfalfa	2900	2500	2400	2600

[1] Yields are calculated in kg ha^{-1}

management. Land charges are not considered due to the experimental farm ownership. Thus, this study compares organic versus conventional crop production on the same farm, assuming that debt charges, equity charges, real estate taxes and other land ownership costs are not affected by the rotation system selected.

Farm labor is typically provided by the owner/operator. The value of this labor will depend upon the types of enterprises and operations involved, outside opportunities available, and other variables. Therefore, we present results with no labor charge and three alternative charges (US$10, US$20 and US$50 h^{-1}). Operations for the two conventional and three organic rotations were implemented by one farm manager. We assume there were no differences among systems and rotations in managerial ability required.

Average conventional corn and soybean prices were equal to or below the average corn and soybean loan rates, as determined by the government program during 1999 through 2001. For this reason, we took into consideration potential loan deficiency payments and assumed the conventional producer received the difference between the average Iowa market price and the corn loan rate of US$1.80 per bushel (25.4 kg) and soybean loan rate of US$5.20 per bushel (27.2 kg) as a deficiency payment. The potential loan deficiency payments were assumed to be US$0.79, US$0.53 and US$0.81 per bushel (27.2 kg), for 1999, 2000 and 2001, respectively. The average Iowa corn price for 1999 and 2001 was US$1.80 per bushel (25.4 kg), so no deficiency payments were assumed. In 2001, corn loan deficiency payments were US$0.02 per bushel.

Iowa organic corn and soybean prices were received by a local elevator source and varied from year to year. Organic corn prices were US$3 per bushel (25.4 kg) for 1999 and 2000 and US$3.20 in 2001. Organic soybean prices were US$15, US$13 and US$14 per bushel (27.2 kg) for 1999, 2000 and 2001, respectively, from the local organic elevator (Heartland Organic Marketing Cooperative, Stuart, Iowa). The assumed deficiency payments were added to the price of organic corn and soybean. Organic oat and alfalfa prices were received by a local source and assumed to be more stable at US$2.00 per bushel (14.5 kg) and US$109 Mg^{-1} for each year, respectively. Organic oat straw average price was US$45 Mg^{-1}. Gross revenues were calculated by multiplying annual commodity prices by annual yields.

Economic returns were calculated by subtracting production costs from gross revenues on an annual (by crop/rotation replication) basis. The annual returns were tested for statistical significance (ANOVA, $P \leq 0.05$). Because returns were first calculated on an annual basis prior to statistical analysis, yearly variability remained in the analysis. We calculated statistical differences among individual treatments using previously described methods (SAS, 1988).

Returns to land, labor and management. Returns for corn within the organic C–S–O and C–S–O–A rotations were not significantly different, at US$655 ha^{-1} and US$674 ha^{-1}, respectively (Table 5). Both returns were significantly higher than the return for the conventional C–S rotation (US$126 ha^{-1}). Returns for soybean within the organic C–S–O and C–S–O–A rotations were not significantly different, at US$1233 ha^{-1} and US$1326 ha^{-1}, respectively. Again, both organic returns were significantly higher than the return for the conventional C–S rotation (US$235 ha^{-1}).

Analysis of the returns to the rotations over 3 years revealed that the organic C–S–O and C–S–O–A rotations were not significantly different at US$734 ha^{-1} and US$739 ha^{-1}, respectively. The average returns to the conventional C–S rotation were significantly lower, at US$180 ha^{-1}. Even with the lower value of the oat crop in the organic rotation, the premium prices for the organic corn, soybean and alfalfa crops led to a more profitable rotation compared to the conventional C–S rotation.

Returns to land and management with various labor charges. As discussed previously, labor charges for the farm owner/operator can only be determined individually, because of the wide variability in opportunity costs for

Table 5. Returns to land, labor and management (US$ ha^{-1}) by crop and rotation, 1999–2001.[1]

Rotation	Corn	Soybean	Oat	Alfalfa	Average
C–S[2] (conventional)	126b	235b			180b
C–S–O (organic)	655a	1233a	309a		734a
C–S–O–A (organic)	674a	1326a	277a	672	739a

[1] Returns within columns followed by the same letter are not significantly different (ANOVA, Tukey's test, $P \leq 0.05$).
[2] C, corn; S, soybean; O, oat; A, alfalfa.

labor. Hourly rates of US$10, US$20 and US$50 were chosen to cover a typical range for Iowa farmers. With a labor charge of US$10 h^{-1}, the organic C–S–O and C–S–O–A rotations produced the highest average returns for corn, at US$590 ha^{-1} and US$610 ha^{-1}, respectively (Table 6). The conventional C–S corn returns were significantly lower, at US$104 ha^{-1}. This was also true for labor at US$20 h^{-1} and US$50 h^{-1}. Increasing the labor charge did not change the statistically significant relationships that existed at US$10 h^{-1}.

The organic C–S–O and C–S–O–A rotations produced the highest average returns for soybean, at US$1144 ha^{-1} and US$1237 ha^{-1}, respectively, at a US$10 h^{-1} wage rate. The conventional C–S soybean returns were significantly lower, at US$163 ha^{-1}. This was also true for labor at US$20 h^{-1} and US$50 h^{-1}. Increasing the labor charge did not change the statistically significant relationships that existed at US$10 h^{-1}.

For the rotational average with a US$10 h^{-1} labor charge, the organic C–S–O and C–S–O–A rotations resulted in similar returns at US$667 ha^{-1} and US$679 ha^{-1}, respectively. The conventional C–S returns were significantly lower at US$133 ha^{-1}. These relationships held through the range of labor costs used.

Returns to land and management with various compost costs. This section presents returns to land and management, with varying compost costs and a constant wage rate of US$10 h^{-1}. For a diversified crop–livestock farm, the cost for compost may be limited to application rates. This was the assumption in the previous sections of this analysis. However, in the case of a producer requiring a purchase of compost, additional costs will accrue, with final cost dependent upon compost availability and location.

With a compost cost of US$18 Mg^{-1}, the conventional C–S rotation produced the highest average return for corn at US$104 ha^{-1} (Table 7). The returns for the organic C–S–O and C–S–O–A rotations were significantly lower, at –US$2 ha^{-1} and US$17 ha^{-1}, respectively. This relationship was also true for compost at US$36 Mg^{-1} and US$54 Mg^{-1}.

Compost was not applied to the organic soybean crop. Thus, the relationship among the various rotations is the same as the US$10 h^{-1} results previously presented. For the rotational average with a US$10 h^{-1} labor charge and US$18 Mg^{-1} compost charge, the organic C–S–O–A rotation had the highest return at US$482 ha^{-1}. The organic C–S–O return was not significantly different at US$405 ha^{-1}. The conventional corn–soybean return of US$133 ha^{-1} was significantly lower than the C–S–O–A rotation. The organic C–S–O rotational return was not significantly different from that of the conventional rotation.

Table 6. Returns to land and management (US$ ha^{-1}) for various labor charges by crop and rotation, 1999–2001.[1]

	Labor charge h^{-1}		
Crop/Rotation	US$10	US$20	US$50
Corn			
C–S[2] (conventional)	104b	84b	20b
C–S–O (organic)	590a	526a	331a
C–S–O–A (organic)	610a	546a	353a
Soybean			
C–S (conventional)	163b	91b	–124b
C–S–O (organic)	1144a	1055a	788a
C–S–O–A (organic)	1237a	1149a	882a
Oat			
C–S–O (organic)	269a	230a	111a
C–S–O–A (organic)	237a	198a	79a
Rotational average			
C–S (conventional)	133b	86b	–52b
C–S–O (organic)	667a	603a	410a
C–S–O–A (organic)	679a	620a	445a

[1] Returns within columns followed by the same letter are not significantly different (ANOVA, Tukey's test, $P \leq 0.05$).
[2] C, corn; S, soybean; O, oat; A, alfalfa.

With a compost charge of US$36 Mg^{-1}, the organic C–S–O–A rotation produced the highest average return at US$284 ha^{-1}. The conventional C–S rotation was substantially lower at US$133 ha^{-1}, followed by the organic C–S–O rotation at US$141 ha^{-1}. The conventional C–S rotation resulted in the highest returns (US$133 ha^{-1}) when compost costs rose to US$54 Mg^{-1}. The C–S–O–A return was US$47 ha^{-1} less at US$86 ha^{-1}, whereas the C–S–O rotational average was –US$124 ha^{-1}.

Returns excluding organic premiums. In the transition years, the 2 years between conventional and certified organic production, producers will not receive organic premium prices, but may receive 'transition' or non-GM premium prices, depending upon the market. In our analysis, excluding organic premiums, conventional grain prices were used: US$1.80 per bushel (25.4 kg) for corn and

US$5.20 per bushel (27.2 kg) for soybean. Average Iowa prices were used for oat and alfalfa crops. Oat straw prices were assumed to be US$18 Mg^{-1}. Oat prices were US$1.30, US$1.30 and US$1.50 per bushel (US$0.09, US$0.09 and US$0.10 kg^{-1}) for 1999, 2000 and 2001, respectively. Average alfalfa prices were assumed to be US$68, US$73 and US$82 Mg^{-1}, respectively, for 1999, 2000 and 2001.

Analysis of the returns to land, labor and management for each rotation over 3 years revealed that the organic C–S–O (US$237 ha^{-1}) and the organic C–S–O–A rotations (US$282 ha^{-1}) held a US$57 ha^{-1} to US$102 ha^{-1} economic advantage, respectively, over the conventional C–S rotation (US$180 ha^{-1}) (Table 8). When a wage rate of US$10 h^{-1} was included for labor, the economic advantage decreased to US$40 ha^{-1} and US$89 ha^{-1} over the conventional rotation for the C–S–O and C–S–O–A rotations, respectively. The economic advantage of the organic C–S–O rotation decreased to US$23 ha^{-1} as wage rates increased to US$20 h^{-1} (US$109 ha^{-1} versus US$86 ha^{-1}), whereas the C–S–O–A remained higher at a US$79 ha^{-1} advantage over the conventional C–S rotation.

With a compost charge of US$18 Mg^{-1} and labor charge of US$10 h^{-1} for all field operations, the conventional C–S rotation would incur the highest return at US$133 ha^{-1}. The organic C–S–O–A rotation would be substantially lower at US$25 ha^{-1}. The organic C–S–O rotational return would return –US$91 ha^{-1}.

Table 7. Returns to land and management (US$ ha^{-1}) for various compost costs by crop and rotation, 1999–2001.[1]

	Compost cost (US$ Mg^{-1})		
Crop/Rotation	**US$18**	**US$36**	**US$54**
Corn			
C–S[2] (conventional)	104a	104a	104a
C–S–O (organic)	–2b	–595b	–1188b
C–S–O–A (organic)	17b	–576b	–1168b
Soybean			
C–S (conventional)	163b	163b	163b
C–S–O (organic)	1144a	1144a	1144a
C–S–O–A (organic)	1237a	1237a	1237a
Oat			
C–S–O (organic)	72a	–126a	–324a
C–S–O–A (organic)	40a	–158a	–356a
Rotational average			
C–S (conventional)	133b	133a	133a
C–S–O (organic)	405ab	141a	–124a
C–S–O–A (organic)	482a	284a	86a

[1] Returns within columns followed by the same letter are not significantly different (ANOVA, Tukey's test, $P \leq 0.05$).
[2] C, corn; S, soybean; O, oat; A, alfalfa.

Discussion

Organic agriculture requires a systems approach of more complexity than conventional farming (Brumfield et al., 2000), with managerial ability significantly affecting economic returns in the organic system. Conventional or transitioning organic farmers may experience a 'learning curve' that may impact weed and crop management in their initial years. Transition years are often considered the most challenging in organic production, with lower yields ('yield drag') reported in the first 2 years of transition from conventional to organic production (Brusko, 1989; Liebhardt et al., 1989; MacRae et al., 1993). However, organic and conventional soybean yields at the Neely–Kinyon LTAR site were similar in all 3 years of the study. These yields were obtained under relatively high managerial ability for producing diverse crops and accurately operating various implements in the organic system. Our results contrast with those of Lockeretz et al. (1981) and Hanson et al., (1997), where the agronomic productivity of organic systems was lower than that of conventional farming systems. In Pennsylvania, however, yields were equivalent in the conventional and organic system after the 3-year rotation (Hanson et al., 1997). Dobbs and Smolik (1996) also obtained higher yields in the conventional soybean fields but conventional fields were planted at different densities than fields in the organic system.

Organic corn yields in our study were similar to conventional yields when yellow feed corn was grown. White corn, grown in 1999 for a specialty food market, is generally a lower-yielding hybrid and did not perform as well as conventional corn without additional fertilization. In all years, corn yields were greatest following 2 years of alfalfa. Our results compare with survey results reported by the Organic Farming Research Foundation (OFRF, 2001), where organic corn yields averaged 95% of conventional yields. Organic corn yields obtained in this study (8246 kg ha^{-1}) were greater than those from earlier studies

Table 8. Rotational returns without organic premiums (US$ ha^{-1}), 1999–2001.

Rotation	Return to land, labor and management	Return to land and management (US$10 h^{-1} wage)	Return to land and management (US$20 h^{-1} wage)	Return to land and management (US$10 h^{-1} wage, US$18 Mg^{-1} compost)
C–S[1] (conventional)	180	133	86	133
C–S–O (organic)	237	173	109	–91
C–S–O–A (organic)	282	222	165	25

[1] C, corn; S, soybean; O, oat; A, alfalfa.

in Iowa (Chase and Duffy, 1991; Duffy, 1991) where the average 10-year organic corn yield (7432 kg ha^{-1}) equaled the average conventional continuous corn yield, but was less than the conventional corn yield in the C–S rotation. Weeds were considered the primary cause for reduced yields in organic systems in California (Clark et al., 1998), but organic premium prices compensated for the yield reduction.

Arguments for and against the inclusion of organic premium prices and/or government program payments in economic analyses are apparent in the alternative agriculture literature (Smolik et al., 1995; Welsh, 1999). One of the motivations for growing organic crops, however, is receiving price premiums (Delate, 2002). We have included organic premium prices and government loan payments in our analysis to reflect the economic reality of Iowa's organic farmers (J. Boes, Heartland Organic Marketing Cooperative, personal communication, 15 October 2002). With corn and soybean government payments for all crops in our analysis, the organic rotations held an economic advantage under average labor and compost costs. Even when we excluded organic premiums, the organic rotations were more economical. Returns to land, labor and management were higher in the organic rotations regardless of whether an organic price premium was received or not.

Returns for the 3-year organic C–S–O rotation (US$734 ha^{-1}) at the Neely–Kinyon LTAR were also greater than the early Iowa organic C–O–A rotation (US$256 ha^{-1}). When the net present value of the early Iowa organic crops was computed by Welsh (1999), a 35.4% premium price was required for the C–O–A rotation to equal the conventional C–S rotation. This contrasted with our results, where the organic C–S–O rotation returns, without any organic price premiums, were greater than the conventional C–S rotation. Government payments may narrow the gap between organic and conventional returns, as shown in the Kansas State University comparison of organic and conventional rotations (Diebel et al., 1995). Organic returns were 143% greater than conventional without government payments and 78% greater with government payments. In another study with federal farm payments, organic costs were lower in organic (excluding labor) and gross income was highest (Smolik and Dobbs, 1991). With a lower cost structure, the individual crops in our organic rotations did not incur substantially lower returns than their conventional counterparts.

In the case of soybean, the organic rotations resulted in significantly higher returns under all situations. Because of higher soybean returns in the organic rotations, the overall rotational average returns to the organic rotations were significantly greater than in the conventional system. This observation verifies local farmer knowledge regarding the importance of including soybean in any organic rotation. Olson and Mahoney (1999) achieved similar results when soybean was included in the organic C–S–O–A rotation, obtaining a mean net return of US$424 ha^{-1} compared to the conventional C–S rotation return of US$385 ha^{-1}.

The issue of off-farm compost costs warrants further investigation. The goal of an organic farm is the establishment of a self-regulating, closed nutrient cycling system. One of the key factors of economic and environmental sustainability is improving soil quality (Wander et al., 1994) and weed management (Temple et al., 1994). For example, Dobbs and Smolik (1996) reported an increase in organic matter in their organic system over the 8-year period. If livestock and compost are available on-farm, economic returns will significantly favor organic systems. When purchased compost costs above US$18 Mg^{-1} were imposed in this study, the organic C–S–O rotation lost the economic advantage over the conventional C–S rotation. As the cost of compost increased to US$36 Mg^{-1} and US$54 Mg^{-1}, the conventional C–S rotation became more competitive. Additional research is needed to determine the average cost of purchasing, transporting and spreading compost for producers without livestock. We anticipate, however, that soil quality will improve over time in the organic systems, thus lowering nutrient input costs. Improvements will occur in organic systems through additional organic matter from longer crop rotations and from compost (on-farm or purchased) and cover crops (Delate and Cambardella, 1999). We also expect to see a reduction in pest management costs as longer crop rotations lead to reduced nematode, weed, insect and disease populations in organic systems (Altieri, 1995). Clark et al. (1998) reported a 50% reduction in pesticide use in organic and low-input systems without a decrease in corn yields.

Conclusions

Our study indicates that organic rotations are competitive with conventional C–S rotations under normal conditions of on-farm labor and management. If the cost of purchased compost can be limited to less than US$18 Mg^{-1}, the economic advantage to organic rotations remains. As compost costs increase from US$18 Mg^{-1} to US$54 Mg^{-1}, the addition of alfalfa (C–S–O–A) in the organic rotation is necessary to remain competitive with conventional C–S rotations. Increasing labor charges from US$10 h^{-1} to US$50 h^{-1} did not affect the rankings of the rotations' returns. Additional labor required by the organic system did not significantly affect the lower production cost advantage.

Our results were predicated on: (1) adequate soil fertility in the organic system; (2) timely pest management (particularly for weed control); and (3) higher organic corn and soybean seeding rates to compensate for losses due to rotary hoeing for weed management. Farms with less fertility or inadequate expertise in organic practices may experience a longer 'transitional effect' in which organic yields remain substantially lower than conventional yields.

As organic farming strives to improve the 'health and productivity of interdependent communities of soil life, plants, animals and people' (USDA-AMS, 2002), an assessment of long-term community benefits (e.g. increased

tax base from value-added production; improved quality of life with less exposure to pesticides; increased farm income after transition to organic production; and greater environmental protection through organic practices) is needed to fully evaluate the long-term effects of adopting organic farming systems. Accounting for externalities associated with agricultural production and compensating farmers for their organic and conservation practices through organic transition, cost-share and organic price premium payments can help increase the sustainability of agriculture in the US.

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Animal production and farm size in Holmes County, Ohio, and US agriculture

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Abstract. *Animal production in US agriculture during 1997 was compared with Holmes County, Ohio, in which half the farms belonged to the agrarian Amish whose small farms have been successful. To compare the intensity of animal production in regard to land that was already devoted solely to domestic feed, the two systems were scaled so that their average farm sizes contained equal land areas devoted to domestic feed and then their animal production per farm was adjusted by the same scaling. By breeding populations, as well as large imports of feed, feeder pigs, calves, and broiler chicks, Holmes County produced three times more milk, four times more broilers, about the same amount of eggs and cattle, and twice the pigs per scaled farm, and hence per given land area, as in the US. Despite the average farm size in Holmes County having been 40% smaller than in Ohio overall, this production yielded more than twice the energy and protein per scaled farm, or per given land area, compared to the US, and required almost twice the feed and 85% as much grazed pasture forage per farm. This was in accord with the fact that feed consumption in Holmes County was twice its harvested crop production, implying a net feed import equal to its crop production. The latter fact was the main contribution to the productivity of Holmes County in excess of the US, and also suggested there would be serious problems in widespread adoption of intensive animal production in regard to agricultural markets, soil fertility and farm nutrient losses through manure application. Energy conversion efficiency for the five animal products and breeding populations was greater in Holmes County than the US (10 and 7%, respectively) and likewise for protein (22 and 13%). Besides imported feed, the higher efficiency of Holmes County was also due to its greater emphasis on milk production, which has benefited from USDA milk price support, modern dairy genetics and dairy nutrition programs. The lower overall efficiency of the US has been partly a result of the fact that beef production and breeding, judged by feed alone, have been the least efficient of the five animal products in energy conversion and nearly the least for protein, regardless of the fact that among the five products, beef cattle are the only animals that nationally derived much of their nutrition from the large national area of grazing land.*

Key words: agricultural productivity, Amish, feed conversion efficiency, protein production

Introduction

This investigation compares the 1997 level of animal production in two agricultural systems, the US and Holmes County, Ohio. This county was studied because it has a high intensity of animal production per area of farmland despite the fact that its average farm size is small. Half of its farms are conventional, and the other half are small Amish farms, but the total contribution of the latter to Holmes County agriculture is not known (Dean Slates, personal communication, Ohio State University Extension Service, Millersburg, Ohio, 10 September 2001). The agrarian Amish are a successful example of traditional agriculture with a long history of using less energy-intensive, but productive agricultural practices in a blend of new technologies and old practices (Johnson et al., 1977; Stinner et al., 1989). In 1997, Holmes County ranked tenth and thirteenth highest among the 88 Ohio counties in gross and net farm income per ha, respectively (Bender, 2001). Animal products accounted for 92% of the marketed economic value of agricultural products in this county (Bender, 2001). Average farm size was nearly 40 ha for Amish farms (Bender, 2001), contributing to an average of 50 ha for all farms in Holmes County during 1997, much less than the mean of 80 ha for Ohio farms and 200 ha for US farms (USDA, 1999a, b).

This investigation showed that, despite small average farm size, Holmes County achieved a much higher intensity of animal production than the national average, mainly because of heavy dairy production and large imports of feed, feeder livestock and broilers through marketing and production contracts. The amounts of energy and protein in animal production per area of farmland were compared between the two agricultural systems by means of average farms scaled to the same size of land area. Conversion efficiencies for this energy and protein were then computed from the consumption of feed and pasture forage by the animal production and breeding populations.

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Methods

Liveweight production and breeding populations

The five animal products in this study were milk, cattle (*Bos taurus*), pigs (*Sus scrofa*), broilers (*Gallus gallus*) and eggs. They essentially represented the national production of animal products because in 1997 they constituted 96 and 93% of the energy and protein in animal products consumed in the national daily diet, respectively (USDA, 2001, p. XIII–5). Breeding populations and the number of animals produced in the US and Holmes County during 1997 were determined from USDA (1999a, 2001).

Total liveweight production in 1997 was reported for the five products in the US by USDA (2001), but only for milk in Holmes County by ODA (1998). Hence, liveweight production of the other four products in the county was calculated, as follows. Since more than half of the cattle sold in Holmes County were dairy calves, total liveweight for cattle was computed from the number sold for calves and older cattle multiplied by the national average liveweights, 160 and 540 kg, respectively (USDA, 1999a, 2001). Likewise, since nearly half of the pigs sold in the county were feeder pigs, total liveweight for pigs was determined from the number sold for feeder pigs and older pigs multiplied by the national average liveweights, 30 kg and 120 kg, respectively (USDA, 1999a, 2001). As a check, application of the respective national average liveweights to the number of calves, older cattle and pigs slaughtered in the US, adjusted for changes in inventory, gave total liveweights almost exactly equal to the above national totals (USDA, 2001). Thus, this procedure should give accurate production totals for Holmes County.

Total production of broilers in Holmes County was computed from the broilers sold and the national average broiler liveweight of 2.2 kg (USDA, 1999a, 2001). Overall egg production in Holmes County was determined from the county inventory of hens and pullets and the national average production of 255 eggs per hen, 0.059 kg apiece (USDA, 1999a, 2001). Regardless of origin of broilers, egg production in both agricultural systems was reduced for broiler-type eggs produced, the latter calculated as the number of market-weight broilers divided by the national hatch and survival rates of 81 and 93%, respectively, in 1997 (USDA, 2001). Then, the breeding population of hens was apportioned between egg and broiler production according to the number of egg-type and broiler-type eggs produced. Since breeding replacements were negligible in number compared to egg and broiler production (Byerly, 1967), they were not subtracted from production.

Some adjustments were also made to the production totals for cattle and pigs. Liveweight cattle production was already adjusted for a decrease in national inventory by USDA (2001) and did not require adjustment for Holmes County because there was little change in inventory (ODA, 1998; Dean Slates, personal communication, Ohio State University Extension Service, Millersburg, Ohio, 10 September 2001). National cattle production (i.e., older cattle) was also reduced by 3%, which represented the production on public grazing lands that were not included in the land area counted in this study (Committee on Government Operations, 1986). It was not necessary to offset pig production in Holmes County for breeding replacement because there was little purchase of sows from outside the county, due to the fact that most pig production was on Amish farms that raised their own sows (i.e., boars were negligible). About one-fifth of the feeder pigs sold by farms in Holmes County remained in the county (Dean Slates, personal communication, Ohio State University Extension Service, Millersburg, Ohio, 10 September 2001) and thus were subtracted from the total sold to avoid double counting with respect to production leaving the county. This correction was the only undocumented verbal information in the calculations for this study and amounted to less than 1% of the energy and protein produced by the five animal products in Holmes County during 1997.

Land area

To compare the production per unit area of farmland, the average farm in the US was scaled down by a factor of 1.43 (i.e., 50 ha ÷ 35 ha) to give the same cropland-equivalent area per farm devoted to domestic feed as in Holmes County (i.e., 35 ha), and the average animal production per US farm was then scaled down by this same factor (Table 1). The land area for average farm size was not total farmland but only land applicable to animal production, namely private pasture and cropland devoted solely to domestic feed consumed in the US or Holmes County, as opposed to exported feed or crops. Public grazing lands were not included because nationally they accounted for 37% of grazing land area (USDA, 1996b, 1999b), but only 3% of beef production (Committee on Government Operations, 1986), which would have disproportionately decreased the production per unit area of farmland. Since average pasture in the US is unproductive compared to cropland (current national average yield is seven times greater on cropland than pasture, Table 1) and would thus decrease the production per unit area of farmland, average farm size in both agricultural systems was based on cropland-equivalent area. In this measure, pasture area was reduced to equivalent cropland area on the basis of relative average yields and then summed with cropland. The resulting cropland-equivalent areas for Holmes County and the US were 35 and 50 ha per farm, respectively (Table 1). The respective areas were 70 and 25% of the mean farm sizes in Holmes County and the US reported by USDA (1999a, b).

Energy and protein conversion efficiencies

Liveweight production totals were converted to energy and protein on the basis of liveweight composition (Table 2). Next, annual consumption of feed and pasture

Table 1. Average yields and areas per farm in the US and Holmes County, Ohio, during 1997.

	US	Holmes Co.
Area	(ha per farm)	
Cropland for domestic feed[1]	36	26
Pasture[1,2]	104	13
Cropland-equivalent[3]	50	35
Yield	(Mg CFU ha^{-1})[4]	
Average crop yield[5]	5.1[6]	4.3
Average pasture yield[7]	0.7[6]	3.0

[1] US, USDA (1999b, 2001); Holmes County, USDA (1999a). Calculated by pro-rating the land area for each crop according to the weight of its domestic consumption as feed relative to its total production.
[2] Includes private grassland, grazed woodland and cropland used only for pasture.
[3] US, $36+(0.7 \div 5.1) \times 104$; Holmes County, $26+(3.0 \div 4.3) \times 13$.
[4] Corn-equivalent feed units (see Methods section).
[5] Food grains and feed crops (Bender, 2001).
[6] The ratio of these two values shows that current national average yield is seven times greater on cropland than pasture.
[7] Byerly (1975); his reported Corn Belt yield was applied to Holmes County.

forage was computed by applying feed consumption factors to liveweight production totals and breeding populations (Table 3). USDA reported feed consumption factors in CFU, or corn-equivalent feed units (*Zea mays* L.). This unit of measure indicated the substitution value of a feed for corn at 13.5% moisture, as determined in numerous feeding trials with different kinds of livestock in various regions of the US. Historically, feed-consumption factors have included grazed pasture forage (Jennings, 1958), and that is still the case nowadays because USDA has been deriving its feed consumption factors by an indexing procedure based on 1969–71 animal weighting factors (Baker, 1998). The 1969–71 factors were based on loss-adjusted minimum feed requirements in which the roughage clearly included pasture forage (Allen et al., 1974). Hence, the feed consumption factors for 1997 in this present investigation are based on feed and pasture forage. This was also confirmed by examination of feed consumption factors for each year since 1909, which show no abrupt, persistent decrease that would suggest permanent omission of pasture forage from some year onwards (Jennings, 1958; USDA, 1972, 1985, 1996a, 2001).

Feed consumption factors were determined for maintenance and replacement of breeding populations (Table 3). It was not necessary to calculate the consumption required for maintenance of dairy cows and egg-laying hens because this was already in the feed consumption factors for milk and egg production resulting from the consumption by cows and hens. Since culled dairy cows were part of liveweight cattle production, their replacement was not charged to milk production. Instead, application of the feed

Table 2. Energy and protein content of animal products on liveweight basis.

Animal product	Energy content ($MJ\,kg^{-1}$)	Protein content (%)
Milk	2.8	3.5
Cattle	8.3	8
Pigs	13.8	6
Eggs	6.5	11.5
Broilers	4.6	9

Byerly (1982).

Table 3. Consumption of feed and pasture forage for production of animal products and maintenance of breeding animals in 1997.

	Feed and pasture forage
Animal product	(kg CFU kg^{-1} product)[1]
Milk	0.76
All cattle	13.3
All pigs	6.4
Eggs	3.9
Broilers	2.6[2]
Breeding animal[3]	(kg CFU per animal)[1]
Maintenance[4]	
Beef cow	2500[5]
Sow	950[6]
Broiler hen	18[7]
Replacement[8]	
Beef cow	5700[9]
Sow	770[10]
Hen	15

USDA (2001), unless noted otherwise.
[1] Corn-equivalent feed units (see Methods section).
[2] Includes 0.2 kg CFU from the above feeding rate for egg production, based on national averages for egg and broiler weights and hatch and survival rates (see Methods section).
[3] Includes male breeding animals.
[4] Maintenance of dairy cows and egg-laying hens was embedded in feed for milk and egg production (see Methods section).
[5] (2400 kg CFU per cow)(1.05), 1 bull for 20 cows.
[6] (900 kg CFU per sow)(1.05), the former, Crampton and Harris (1969, p. 417) and the latter, 1 boar for 20 sows.
[7] 70 and 30% of the metabolizable energy in feed goes to eggs and maintenance, respectively (Byerly, 1982). Roosters are negligible.
[8] See Methods section for replacement rates and for feed imputed to cattle production for replacement of culled dairy cows.
[9] (2700 kg CFU per heifer)(2)(1.05), heifers are 2 years old.
[10] (730 kg CFU per gilt)(1.05).

consumption factor to liveweight cattle production retroactively imputed previous consumption by culled dairy cows to cattle production (Byerly, 1975). The portion of the breeding population replaced annually was the inverse of

the following values for productive life (years): dairy cows, 3; beef cows, 5; sows, 3; and hens, 1 (USDA, 2001).

Another consideration for consumption was that Holmes County imported a large number of feeder pigs, calves and broiler chicks, for which the eventually finished liveweights included the imported weights. Hence, to impute consumption for the imported weights, the number of imported calves and feeder pigs were determined from USDA (1999a), which were multiplied by national average liveweights of 160 and 30 kg, respectively, and then by feed consumption factors (USDA, 2001). Regardless of origin of broiler eggs, feed for broiler production included feed for egg production based on the above egg and broiler weights and hatch and survival rates.

Consumption was also partitioned between feed and pasture forage because four of the five products were produced from little or no pasture forage compared to beef cattle. This allowed comparison of beef cattle with the other products on the basis of feed alone. Feed and pasture forage constituted 40 and 60%, respectively, of the national diet in CFU for beef cattle, and 90 and 10% for dairy cattle (Byerly, 1975; Lin et al., 1990). It was assumed that these proportions also applied to Holmes County. Since the national diet for pigs and chickens was almost entirely feed (Lin et al., 1990), total consumption of feed was the sum of beef and dairy feed plus the overall consumption by pigs, eggs and broilers. Hence, consumption of pasture forage was determined only from beef and dairy cattle.

The annual consumption of feed and pasture forage in CFU was converted into energy and protein on the basis of US grade 2 dent corn with an oven-dry content of 10.6% protein and 18.4 MJ kg^{-1} (2000 kcal lb^{-1}), both then adjusted for 13.5% moisture content (Crampton and Harris, 1969). Finally, conversion efficiencies were calculated as ratios of energy or protein between the animal production and the consumption of feed and pasture forage, and, in the case of cattle, feed alone was also considered.

Results

Liveweight production and breeding populations

With the average US farm scaled to contain the same cropland-equivalent area devoted to domestic feed as in Holmes County, the average dairy cow herd per farm was four times larger in Holmes County than the US, but produced only three times more milk (Tables 4 and 5). This relative milk production was smaller than the relative dairy herd size mostly because Amish farmers in Holmes County preferred to market high-butterfat milk from Jersey and Guernsey cows even though milk volume per cow was less compared to that of other dairy breeds.

In reverse of the situation for dairy cow herds, the average beef cow herd was nearly four times larger in the US than in Holmes County, but liveweight production of older cattle per farm was only 1.5 times greater (Tables 4 and 5). This relative production was less than the ratio of 1.9 expected from the dairy and beef breeding populations (Table 4) in terms of beef yearlings and culled beef and dairy cows, given the average productive life of 3 and 5 years for dairy and beef cows, respectively (USDA, 2001). This relative production was less than expected because

Table 4. Animal products and breeding populations per farm in the US and Holmes County during 1997.

	US[1]	Scaled US[2]	Holmes Co.[3]
Animal product		(Number per farm)	
Milk (1000 liters)	31.0	21.7	64.3
Calves	0.5	0.4	10.3
Older cattle	15.4	10.8	7.6
Feeder pigs	0	0	33
Older pigs	42	29	46
Eggs (1000)[4]	30.6	21.4	27.3
Broilers (1000)	3.5	2.5	9.2
Breeding population			
Dairy cows[5]	4.2	2.9	11.7
Beef cows[5]	15.7	11.0	3.0
Sows	2.6	1.8	4.0
Hens (eggs)[6]	121	85	107
Hens (broilers)[6]	18	13	48

[1] Animal numbers and 2.2 million farms, USDA (2001).
[2] This is the first column scaled down by a factor of 50 ha ÷ 35 ha, or 1.43, to give the same cropland-equivalent area per farm devoted to domestic feed as in Holmes County, namely 35 ha (Table 1).
[3] Animal numbers and 1404 farms, USDA (1999a).
[4] Reduced for the number of eggs devoted to broiler production (see Methods section).
[5] Includes heifers, 2 years and older.
[6] Includes pullets. Hen flocks apportioned according to production of egg-type eggs and broiler-type eggs (see Methods section).

Table 5. Liveweight of animal products per farm in the US and Holmes County during 1997.

Animal product	US[1]	Scaled US[2]	Holmes Co.[3]
		(Mg per farm)	
Milk	31.9	22.3	66.4[4]
Calves	0.08	0.06	1.6
Older cattle	8.6	5.8	4.1
Feeder pigs	0	0	1.0
Older pigs	5.0	3.5	5.6
Eggs	1.8	1.3	1.6
Broilers	7.8	5.4	20.3

[1] Reported by USDA (2001).
[2] See Footnote 2 in Table 4.
[3] Except for milk, calculations based on USDA data (see Methods section).
[4] Reported by ODA (1998).

Table 6. Amount of energy and protein in animal products per farm in the US and Holmes County during 1997 (Tables 2 and 5).

	Energy		Protein	
	Scaled US	Holmes Co.	Scaled US	Holmes Co.
Animal product	(GJ per farm)		(Mg per farm)	
Milk	62	186	0.78	2.30
Cattle	49	47	0.47	0.46
Pigs	48	91	0.21	0.40
Eggs	9	10	0.15	0.18
Broilers	25	93	0.49	1.80
Total	193	427	2.10	5.14

Holmes County imported a large number of calves, many of which were finished as older cattle.

Total liveweight production of calves and older cattle per farm was roughly the same between the two agricultural systems for two reasons (Table 5). One is that the total herd of beef and dairy cows per farm was nearly equal between the systems (Table 4), resulting in about the same number of weaned calves, but not equivalent production from these calves. The other reason was that the greater emphasis on yearling production from weaned calves in the US was somewhat balanced in Holmes County by the large import of feed and calves and by the quicker turnover time in productive life of dairy cows compared to beef cows, resulting in more culled cows from the much larger dairy cow herd per farm in the county.

Total liveweight pig production per farm, and hence per unit area of cropland-equivalent, was about twice as great in Holmes County as in the scaled US system (Table 5). This ratio was also true for the number of sows per farm (Table 4).

Although egg production was reduced 31% in Holmes County for eggs devoted to broiler production, and only 13% in the US, egg production per scaled farm was 1.2 times greater for the former compared to the latter (Tables 4 and 5). Liveweight broiler production per scaled farm was also nearly four times greater in Holmes County than the US, partly because 90% of the broiler production in the county was contract production by Amish farmers as an add-on practice to their dairy farming (Dean Slates, personal communication, Ohio State University Extension Service, Millersburg, Ohio, 10 September 2001). The relative size between the two agricultural systems for egg-type hen flock per farm was the same as the relative egg production, and likewise for broiler-type hen flock and broiler production, only because the overall hen flock was apportioned according to the relative production of egg-type and broiler-type eggs (see Methods section).

Imported animals

The number of all sold cattle per farm in Holmes County, 17.9, minus the number of weaned calves from the dairy and beef cows, 13.2 (i.e., 14.7 × 0.90, number of cows and national calving rate), yielded 4.7 imported calves per farm (Table 4, assumed little change in inventory). The number of all pigs sold per farm in Holmes County, 79, minus the number of weaned pigs from the sows, 70 (i.e., 4.0 × 8.7 × 2, number of sows, average litter size, and number of farrowings per sow), yielded 9 imported feeder pigs per farm (Table 4, assumed little change in inventory). These imported animals represented an imported liveweight per farm of 750 kg in calves and 270 kg in feeder pigs, for which consumption of feed and pasture forage was imputed to Holmes County.

Energy and protein in production and consumption

Between the two agricultural systems, milk followed by broilers in Holmes County resulted in the most energy and protein per farm, and pigs almost tied with broilers in energy (Table 6). Within Holmes County on a per-farm basis, and consequently in reality at the county level, milk yielded 45% of the energy and protein in the five products. But, milk production and breeding population together accounted for less than 25 and 10% of the consumption of feed and pasture forage, respectively, in the county (Tables 7 and 8). Per farm, and hence per unit area of cropland-equivalent, the milk in Holmes County contained more protein and almost as much energy as the five products combined for the US, but its production and breeding population required only 40% as much feed as the five US products, and less than 10% as much pasture forage. Broilers in Holmes County yielded more protein per farm than milk, cattle and broilers together in the US, albeit that the broiler production and breeding population needed only three-fourths as much feed per farm as the three US products.

Within the US on a per-farm basis and consequently in reality at the national level, milk supplied at least one-third of the energy and protein in the five products, but its production and breeding population required less than 15% of the feed consumption and only a few percent of the pasture forage (Tables 6 and 8). At the farm and national levels, the production of cattle in the US resulted in as much energy as pigs and almost as much protein as

Table 7. Combined consumption of feed and pasture forage for animal production and breeding populations per farm in the US and Holmes County during 1997 (Tables 3, 4 and 5).

	Scaled US	Holmes Co.
Animal product	(Mg CFU per farm)[1]	
Milk	17	50
Cattle	78	76
Imported calves	–	10[2]
Pigs	22	42
Imported feeder pigs	–	1.7[2]
Eggs	5.1	6.2
Broilers	14	53[3]
Subtotal (rounded)	136	239
Breeding population		
Maintenance[4]		
Beef cows	27.5	7.5
Sows	1.7	3.8
Broiler hens	0.2	0.9
Replacement[5]		
Beef cows	12.5	3.4
Sows	0.5	1.0
Layer hens	1.3	1.6
Broiler hens	0.2	0.7
Subtotal (rounded)	44	19
Total	180	258

[1] Corn-equivalent feed units (see Methods section).
[2] (750)(13.3 × 10^{-3}) and (270)(6.4 × 10^{-3}), respectively. Factors are imported liveweight in kg (see Results section) and feed consumption factor in Mg CFU (Table 3).
[3] Includes feed for imported broiler chicks by means of feed consumption factor (Table 3).
[4] Maintenance of dairy cows and egg-laying hens was embedded in feed for milk and egg production (see Methods section).
[5] Feed was charged to cattle production for replacement of culled dairy cows (see Methods section).

broilers, although its production and breeding needed nearly twice the feed for pigs or more than three times the feed for broilers, as well as almost all of the national pasture forage consumed. Again at both levels, cattle yielded one-fourth of the energy and protein in the five US products, but its production and breeding required nearly 45% of the feed consumption and almost all of the consumed pasture forage.

We could say that Holmes County produced about the same amount of energy (or protein) per farm as the US in cattle and eggs, twice in pigs, three times in milk, and four times in broilers (Table 6). However, these ratios are merely a reiteration of the above ratios for liveweight production, because each energy or protein content (Table 2) was applied to the liveweight production in both agricultural systems (Table 5), thus canceling out in the ratios. The energy and protein contents did not cancel out in the ratios for the five animal products combined, with Holmes County having produced 2.2 times more energy per farm and 2.5 times more protein than the US (Table 6).

Table 8. Separate consumption of feed and pasture forage for animal production and breeding populations per farm in the US and Holmes County during 1997 (Table 7).

Production and breeding population	Scaled US	Holmes Co.
	(Mg CFU per farm)[1]	
Feed		
Milk	15	45
Cattle	47	39
Pigs	24	49
Eggs	6	8
Broilers	14	55
Subtotal	106	196
Pasture forage		
Milk	2	5
Cattle	71	58
Subtotal	73	63
Total	179	259

For the partition between feed and pasture forage, see Methods section.
[1] Corn-equivalent feed units (see Methods section).

This production, including breeding populations, required 1.9 times as much feed per farm as in the US, but only 85% as much pasture forage (Table 8).

Compared to the US, the greater production of protein and energy per farm in Holmes County was achieved with less feed and pasture forage per farm for the breeding populations on an absolute basis and also relative to the consumption for animal production (Table 7). These facts were also true for feed alone.

Consumption by breeding populations relative to consumption for animal production was about the same between the US and Holmes County for pigs, eggs, and broilers (Table 7). In Holmes County, it was relatively greater for milk and lower for cattle compared to the US. In the former case, the breeding population represented a greater relative demand in Holmes County because its prevalent Jersey and Guernsey breeds yielded less milk volume per cow than in the US. In the latter case, the beef cow herd represented a smaller relative demand in Holmes County because a significant amount of cattle production in the county resulted from culled dairy cows and imported calves.

Energy and protein conversion efficiencies

The efficiencies for conversion of feed and pasture forage (Table 9) were in fair agreement with values reported by Bondi (1982) and Ensminger (1991) and did not exceed feasible efficiencies (Balch and Reid, 1976; Byerly, 1967). For production alone in milk, eggs and broilers, the efficiencies were mathematically the same between US and Holmes County because consumption was calculated on the basis of liveweight production, thus

Table 9. Energy and protein conversion efficiencies between animal production and consumption of feed and pasture forage in the US and Holmes County during 1997 (Tables 6 and 7).

	Energy				Protein			
	Production alone[1]		Production and breeding		Production alone[1]		Production and breeding	
Animal product	Scaled US	Holmes County	Scaled US	Holmes County	Scaled US	Holmes County	Scaled US	Holmes County
				(%)				
Milk	23	23	23[2]	23[2]	50	50	50[2]	50[2]
Cattle	3.9	3.4	2.6	3.0	6.6	5.8	4.3	5.2
Cattle, feed only[3]	10	8.6	6.5	7.6	17	15	11	13
Pigs	14	13	12	12	10	10	9.5	9.3
Eggs	10	10	8.8	8.1	31	31	25	25
Broilers	11	11	11	11	38	38	37	36
Five products	8.9	11	6.7	10	17	23	13	22

Data in Table 7 were converted into energy and protein (see Methods section).

[1] For milk, eggs and broilers, efficiencies were mathematically the same between US and Holmes County, but for cattle and pigs, they were different because of imported animals in Holmes County (see Results section).

[2] For dairy cows, maintenance was embedded in milk production, and replacement was charged to cattle production (see Methods section).

[3] Assumed that the national 40 and 60% respective proportion of feed and pasture forage in beef cattle diet also applied to Holmes County (see Methods section). Since feed is only 40% of total consumption and since all production from feed and pasture forage is still counted (Table 6), these percentages are 1 ÷ 0.40, or 2.5 times greater (within rounding error) than the above respective percentages for cattle on feed and pasture forage.

permitting the latter to cancel out of the conversion ratio. In other words, efficiency was determined by energy or protein content (Table 2) and feed consumption factor (Table 3). For cattle and pigs, the efficiencies were different between the US and Holmes County because feed consumption in Holmes County applied to imported animals as well as production (see Methods section).

Among the five animal products for production alone, milk had the highest efficiencies for conversion of feed and pasture forage into energy and protein, 23 and 50%, respectively, followed by broilers with 38% for protein, but only 11% for energy (Table 9). Cattle in the US and Holmes County had the lowest efficiency for energy, 3–4%, and protein, 6–7%. Even on the basis of feed alone, cattle production, including that from pasture forage, was lowest in energy efficiency, 9–10%, and second lowest in protein, 15–17%.

Energy efficiency for production of the five products in the US and Holmes County was 9 and 11%, respectively, and protein efficiency, 17 and 23% (Table 9). With breeding populations, the respective efficiencies for energy were 7 and 10%, and for protein, 13 and 22%. With inclusion of breeding populations, the relative decrease in conversion efficiencies was less for pigs, eggs and broilers compared to milk and cattle (Table 9). Cows have a large feed cost for maintenance and replacement, the latter in which the 2 years to raise heifers for replacement are proportionally not much smaller than the productive life of 3–5 years for cows. The inclusion of beef cows in Holmes County produced only a small relative decrease in conversion efficiencies as a result of no beef breeding population imputed for the imported calves or culled dairy cows (Table 9).

Discussion

Farm size and productivity

Scaling of farm size allowed comparison of the US and Holmes County over equal areas of cropland-equivalent devoted to animal production, i.e., 35 ha per farm. Animal production could have been calculated on a per-hectare basis, but potentially this could have been confused with per-hectare productivity in other studies. The latter unit hectare was land devoted to a particular animal or crop, but our unit hectare would have been apportioned among all animals and domestic feed crops on the average farm.

The US was favored by our use of cropland-equivalent area for scaling farm size because it resulted in a greater reduction of land area assigned per farm in the US than Holmes County, thus leading to a larger increase in production per given area for the US. The larger reduction in land area for the US was due to the greater proportion of pasture in the US than in Holmes County (i.e., 74 and 33%, respectively, Table 1) and the greater reduction of unit pasture area into cropland-equivalent area in the US than in Holmes County (i.e., respective multiplication factors of

0.14 and 0.70 from the ratio of pasture yield to crop yield, Table 1). If the direct sum of pasture and cropland area had been employed instead of cropland-equivalent area, then the mean area per farm would have been 140 and 39 ha in the US and Holmes County, respectively (Table 1). This would have given a scaling factor of 3.6 (i.e., 140 ÷ 39) instead of our factor of 1.43, thus resulting in US production values per scaled farm (Tables 4, 5 and 6) that would have been 2.5 times smaller than in this study (i.e., 3.6 ÷ 1.43). Moreover, the US was favored by our omission of the large national area of relatively unproductive public grazing land in the calculation of average farm size, including omission of its minor beef production in national cattle production (see Methods section).

Compared to the US, the analysis showed that Holmes County produced 2.2 times more energy per scaled farm and hence per given area, and 2.5 times more protein. This production required 1.9 times as much feed per farm and 90% as much pasture forage. The ratio of 1.9 is in expected agreement with independent calculations that feed requirements in Holmes County were 2.0 times its harvested crop production in 1997, the latter implying that the county had a net import of feed equal to its crop production (Bender, 2001). From these numbers, if Holmes County were to reduce its feed requirements by half (i.e., have no net import of feed), then compared to the US per farm, its feed requirements would be about the same and its energy and protein production would roughly be little greater. This suggests that the primary reason for the greater productivity in Holmes County was the large import of feed, which enabled the county to employ larger breeding populations per farm and to import substantial numbers of feeder pigs, calves and broiler chicks. Agreement was expected between the above ratios of 1.9 and 2.0 because both ratios effectively compare feed requirements to feed production from cropland devoted solely to domestic feed.

The average farm size in Holmes County was 50 ha, only 60% of the mean size of 80 ha in Ohio (USDA, 1999a). Despite the small farm size in Holmes County, the analysis found that its energy and protein production per scaled farm, and hence per given area, was more than twice as much compared to the US (i.e., scaled farms had the same cropland-equivalent areas). This result concurs with the observation by Rosset (1999) that the total output of crops and animals per unit area is greater for small farms than large ones in various industrial and developing countries. For example, across the US in 1992, farms with a median size of 11 and 23 ha, respectively, had about four and two times the average gross dollar output per ha that was similar for consecutive categories within a range of 80–280 ha in median farm size (Rosset, 1999). The two respective size categories had 2.5 and 1.5 times the average net dollar output per ha that was again similar for the larger consecutive size categories. In addition, Tomich et al. (1995) have noted that there is much evidence in developing countries for a decline in total factor productivity per unit area as farm size increases, the well-known 'inverse relationship' between farm size and output. All these findings are partially explained by the observation that it would be easier for a farmer to achieve a higher density of farm inputs per ha, and thus higher productivity, on a small farm than a large one, simply because the total farm inputs that the farmer could feasibly control during the year would be spread over a smaller land area, as exemplified by small farms in Holmes County.

Energy and protein conversion efficiencies

Energy and protein efficiencies for the five products and breeding populations combined were greater in Holmes County than in the US (Table 9). One reason for the higher overall efficiency in Holmes County was that its beef and pig breeding populations were smaller relative to production than in the US, as a result of imported calves and feeder pigs in the county and more culled dairy cows per farm credited to cattle production.

Another reason for the higher overall efficiency in Holmes County was that, compared to the US, energy and protein production per farm in Holmes County was proportionally derived more from milk and broilers and less from cattle (Table 6). With breeding populations in the US or Holmes County, milk was three times and broilers about twice as efficient in energy and protein as cattle, judged by feed alone (Table 9). In other words, the higher overall efficiency in Holmes County have been largely a result of its milk production benefiting from USDA milk price support, modern dairy genetics and dairy nutrition programs.

In contrast to Holmes County, the lower efficiency in the US has been partly due to the utilization of the large national area of grazing land by beef cattle, the only animal among the five products that can derive much of its nutrition on grazing land far away from the farmstead (see Methods section). However, beef production has been accompanied by greater than adequate consumption of feed, driven more by price and government policy than by nutritional necessity for cattle or people (NRC, 1989). Hence, the lower overall efficiency in the US has been due not solely to utilization of grazing land, but also to the fact that beef production and breeding, judged by feed alone, have been the least efficient of the five animal products in energy conversion and nearly the least for protein (Table 9).

Implications

The US would not be able to emulate the intensity of animal production in Holmes County because national and global agricultural markets would be disrupted by our increased export of animal products and our substantial import of feed. This feed import by the US would create an undesirable dependency on other nations for feed, analogous to our national petroleum imports or the large food imports by poor Third World countries.

The intense production of animals in Holmes County is symptomatic of large ratios of expenses to gross income in

US agriculture that force small farms to produce large amounts of animal products in order to make adequate net incomes (Bender, 2001). Farmers in Holmes County have maintained a low level of farm inputs and have spread their costs by making diverse use of buildings, labor and other inputs (Stinner et al., 1989). They have also operated a variety of enterprises on their farms to receive more income through value-added products. The federal government could increase farm income through price supports and other policy.

The soils in Holmes County benefit from a level of nutrients through imported animal feed that could not be attained by a majority of the counties in the US. The feed requirements in Holmes County were twice the harvested crop production of the county, implying a net feed import equal to the harvested crops (Bender, 2001). As a consequence, soil productivity in the county has benefited from a net import of nutrients roughly equal to the nutrients in the total crop harvest, the latter already being returned as manure to cropland with some losses. Hence, there may likely be local environmental problems such as soil build-up, runoff and leaching of nitrogen and phosphorus associated with application of large volumes of manure from imported feed to small areas of cropland (NRC, 1993). It would be physically impossible for a majority of the counties in the US to achieve a relative net import of this size, unless feed was imported from other nations. For example, in 1997 only one-fourth of the counties in Ohio had a net import of feed, none approaching the relative magnitude of Holmes County, and the other three-fourths, a net export (Bender, 2001). Thus, national adoption of organic farming practices will not result in soils as fertile as Holmes County unless other farming practices are employed besides return of animal manure to cropland.

Conclusions

Despite its average farm size being 40% smaller than in Ohio overall, Holmes County produced in 1997 more than twice the energy and protein per scaled farm, and hence per given area, than the US. This reflected the general pattern noted by Rosset (1999) and Tomich et al. (1995) that small farms have greater total output of crops and animals per given land area than large farms. Moreover, energy conversion efficiency for the five animal products and breeding populations was greater in Holmes County than in the US by 10 and 7%, respectively, and likewise for protein, 22 and 13%. The greater production and efficiency in Holmes County have been a result of its exceptionally large import of feed and feeder animals and also its efficient milk production, benefiting from USDA milk price support, modern dairy genetics and dairy nutrition programs.

The lower conversion efficiency in the US has been partly due to the utilization of the large national area of grazing land by beef cattle, accompanied by more than adequate consumption of feed, such that, judged by feed alone, beef production and breeding have been the least efficient of the five animal products in energy conversion and nearly the least for protein. The excessive consumption of feed by beef cattle has been driven mostly by prices and government policy, and should be reduced to levels sufficient for cattle and human nutrition.

Holmes County has been distinguished by successful, small-scale farming. Its farmers have retained various traditional practices, but they have also adopted some modern technologies and practices that can be profitable on small farms. Hence, these small farms are not completely self-contained and independent from US agriculture. In return, some farming practices in Holmes County have proven to be productive and less energy-intensive and should be incorporated into conventional American farming.

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Producer satisfaction with returns from farmers' market related activity

Ramu Govindasamy, John Italia, Marta Zurbriggen and Ferdaus Hossain

Abstract. *Over 61% of farmers who sell agricultural products through farmers' markets are satisfied with the returns they generate. Producers who are 50 years of age or older and those who retail at least 70% of the dollar value of the products are more likely to be highly satisfied with their profit margin from farmers' markets. A strong positive relationship is documented between profit margin satisfaction and growers who offer organic produce for sale. Furthermore, the results suggest that producers with farmers' market businesses in the growing stage are more likely to be highly satisfied with profit margins.*

Key words: farmers' markets, logistic model, producer characteristics

Introduction

The agricultural sector is critically important not only for the farmers, but also for nonfarming communities of New Jersey and other northeastern states. In addition to generating income for the farmers, a healthy farm sector helps preserve the rapidly disappearing open space in New Jersey and other parts of the region. Farmers' markets play an important role in supporting the farming sector of the region. These markets provide small-scale producers the opportunity to sell directly to the consumers without going through other market intermediaries. By eliminating the need for the services of middlemen, farmers are able to capture a greater share of consumers' food dollars.

Agriculture in New Jersey and other northeastern states is structurally different from that in the rest of the country in terms of product mix, farm characteristics and general farming environment. For instance, compared to the national average, New Jersey agriculture is characterized by a much smaller farm size with a far wider range of product mix. Further, in the urban and suburban settings of the region, farmers must deal with higher land prices and input costs, and much greater regulatory burden compared to those in other states (Tavernier et al., 1996). The higher costs of production, along with development pressures, represent serious threats to the farm sector of the state. On the other hand, the socio-economic setting of the state provides an opportunity for the farmers to be creative in their production and marketing operations, essential for success in their farm businesses.

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The high density and diversity of population in New Jersey and neighboring states provide an ideal opportunity for farmers to sell directly to consumers and receive higher prices for their products. Farmers' markets represent the most convenient and widely used direct marketing channel for the farmers. The socio-economic structure of the area offers a perfect environment for the development of farmers' markets, which, unlike other marketing operations, can be readily moved to convenient locations to better serve the customers.

Growing concerns with nutrition and healthy eating habits also support the expansion and continued success of farmers' markets. Consumers continue to increase their consumption of fresh fruits and vegetables, with annual per capita expenditure on fresh produce measured in constant dollars increasing from US$59.28 in 1980 to US$102.78 in 1992 (Smallwood et al., 1994). Northeastern growers are well suited to capitalize on this trend, since the region's per capita income ranks among the highest in the country (Govindasamy and Nayga, 1996).

In today's economy, small farmers face strong national as well as international competition. In such an environment, the viability of farms, especially the small-scale farms, critically depends on these farmers' ability to identify and serve 'market niches' that offer price premiums over the mass markets. In this respect, the smaller scale of farms in the northeastern US (relative to the national average) may be an advantage in the sense that the smaller size may allow greater flexibility to respond quickly to market opportunities. Farmers' markets provide growers the best opportunity to remain in direct contact with consumers, to understand their wants and preferences, and to adjust production rapidly to better serve the consumers' needs.

Studies indicate that price, freshness and social atmosphere are the main factors responsible for drawing

consumers to the farmers' market outlets (Govindasamy et al., 1998). The producer-marketers can utilize these aspects of consumer preference to their advantage and cater to niche areas in the produce market—a marketing strategy that the mass producers and marketers are generally unable to exploit. The smaller-scale growers are in the best position to take advantage of the price premium available in the specialized products markets, by meeting the unique demands for specialized products (Lyson et al., 1995). Farmers' markets provide the growers the ideal opportunity to serve these consumer needs.

Growth of farmers' markets not only creates opportunity for small, specialized producers to increase profitability, it also promotes social interaction between farming and nonfarming communities. In addition to offering a unique shopping experience for the consumers, these markets generally have positive impacts on downtown areas. For these positive spillover benefits, urban development strategies are often tied in with the organization of these markets (Sommer, 1985).

As part of efforts to strengthen the New Jersey agricultural sector, as well as to better meet consumer needs, The North Jersey Farmers' Market Council, New Jersey was formed to organize farmers' markets at prime consumer locations in the state. The council has already developed over 30 farmers' market outlets and more are expected to begin operation next season. Initial indications are that these markets are being well received by the communities, and there is growing demand for these outlets.

Given the positive response from communities and high demand for direct-to-consumer farm retail outlets in many communities, identification and recruitment of potential vendors are crucial for the development and expansion of the farmers' markets. Successful expansion of these direct market outlets requires that both consumers and grower-marketers find these markets beneficial for them. Grower satisfaction with the farmers' market is a key factor that will determine their participation in these markets. Targeting producers who are most likely to be satisfied with the returns generated at farmers' markets should allow market organizers to retain the existing participants and recruit new customers.

Despite the importance of the farmers' markets as a direct marketing channel for the farmers, very little is known about the satisfaction level of the farmers who participate in these markets. This study explores the issue of grower-marketers' satisfaction with respect to their returns at the farmers' market operation. Although the satisfaction of an operator with his/her business is a multidimensional issue, this study focuses on one aspect of farmer satisfaction, i.e., the profit margin from the farmers' market operations. Specifically, the objective of this study is to identify the characteristics of producers who are likely to be satisfied with returns from farmers' markets. Such information will help the organizers to evaluate the future growth prospect of these markets as well as to identify the likely recruitment targets for the existing and new outlets. The study employs a logistic model approach to decompose the effects of various producer characteristics in predicting growers' satisfaction with the returns from farmers' market operations.

Data Description

The data for the study came from a survey of New Jersey producers who retail at farmers' markets. The survey was conducted in 1997 by Rutgers Cooperative Extension to document the key characteristics of farmers who retail various farm products (primarily fruits and vegetables) at these outlets. The survey collected information on various aspects of growers' production and marketing operations, such as area cultivated, sales volume, farm ownership status, stage of business development, number of hired employees, and number of family members involved in the farm operation. Information was also collected on the growers' marketing-related activities, such as days of market participation, market location, and products sold, including related/value-added products sold. In addition, the survey gathered socio-demographic information of the growers, including age, ethnicity, education, and family size.

A total of 144 questionnaires were mailed at random to New Jersey growers in 1997. The packet included a self-addressed envelope and a cover letter that explained the purpose of this research. A dollar bill was included as a small recognition for the participant's time and as an incentive to increase the rate of response. A total of 68 out of the 144 questionnaires were returned, giving a 47% response rate. However, 10 of these 68 surveys were excluded from the analysis for the following reasons. Four were returned because of incorrect addresses. One respondent had retired; another had sold the farm; one grower was in the process of becoming a vendor; and two addressees were not farmers. One questionnaire was not included because it was received after the data had already been compiled and analyzed. Among the remaining 58 completed surveys, 22 were from farmers who sold directly to consumers but not through farmers' markets. After excluding these 22 completed responses, the remaining 36 usable questionnaires were used for the present analysis.

The producers that retail through farmers' markets were from 24 to 68 years old, with a mean age of 43 years. The majority of the sample was male and had at least a high school diploma. With respect to the level of education achieved, 37% of respondents had some college background, 34% had graduated from college, 3% had some graduate education and 6% had completed a Masters degree. Approximately 97% of the 36 respondents were Caucasian.

About 63% of the respondents indicated that their businesses were still growing, while the remaining 37% described their business as 'not growing'. Regarding the

land on which they farmed, almost 78% of respondents indicated that they owned it.

Table 1 shows the distance traveled by producers to reach the nearest and farthest farmers' markets, respectively. On average, each farmer traveled 44 km (27 miles) to the closest market and 68 km (42 miles) to the farthest one. The ranges were 2–113 km (1–70 miles) for the nearest markets and 8–121 km (5–75 miles) for the furthest markets. Thus, overall, producers spent at least 1 hour (round trip) on the road to market their commodities. If the time taken to load and unload their vehicles is considered, the opportunity costs of travel could be substantial, since producers often have to harvest and retail on the same day.

The average producer who responded tended to retail the products that he/she produced. Approximately 4% of those who responded wholesaled less than 40% of the dollar value of products that they produced; about 12% wholesaled 50% of their produce; 6% sold 60% at wholesale; 3% wholesaled 75% of their produce; and 3% wholesaled 80% of the dollar value of the commodities produced. Approximately 30% of growers surveyed indicated that they did not wholesale any of their produce.

Among the 31 respondents (out of 36) who revealed the value of their gross sales from all retail activities in the previous year, 7% reported sales below US$5000, while 19% reported sales between US$5000 and US$14,999. Sales between US$15,000 and US$29,999 and between US$30,000 and US$59,999 were each reported by 13% of the respondents, while the categories US$60,000–99,999, US$100,000–149,999 and US$150,000–199,999 had 7% responses each. About 10% fell in the US$200,000–249,999 range, while the US$250,000–299,999 and US$300,000–349,999 categories included 3% each. The US$350,000–499,999 bracket accounted for 10% while another 3% of these respondents reported retail sales of US$500,000 and more (Fig. 1).

Regarding the relative importance of various products as sources of revenue, 44% of the respondents identified tomatoes (*Lycopersicon esculentum*) as the most important revenue source. Corn (*Zea mays* L.) was mentioned by 9%, while each of the following products was identified by 6% of the growers: herbs, peaches (*Prunus persica*), flowers, apples (*Malus sylvestris*), and leafy green vegetables [e.g., spinach (*Spinacia oleracea* L.)]. Other important revenue sources mentioned were: string beans (*Phaseolus vulgaris*), eggplants (*Solanum melongena* L.), berries, basils (*Ocimum basilicum*), and mums (*Chrysanthemum* sp.), where each was mentioned by 3% of the survey respondents. Other products mentioned were: peppers (*Capsicum annum* L.) ($n = 18$), squash (*Praecitrullus fistulosus*) ($n = 11$), potatoes (*Solanum tuberosum* L.) ($n = 7$), cucumber (*Cucumis sativus* L.) ($n = 5$), pumpkins (*Cucurbita pepo* L.) ($n = 5$) and apple cider ($n = 5$).

Participants were asked to indicate how satisfied they were with the profit margin obtained from farmers' market operations. Of the 36 marketers who responded, 34% were very satisfied, 27% were satisfied, 33% were somewhat satisfied, and 6% were not at all satisfied with the profit margin.

Table 1. Distance traveled to farmers' markets.

Distance (km)	Nearest farmers' market	Farthest farmers' market
	Number of respondents	
0–9	4	1
10–19	4	2
20–29	5	2
30–39	4	0
40–49	6	5
50–59	1	2
60–70	1	4
70–79	2	2
80–89	4	6
90–99	1	2
100 and more	1	5
Average distance	44	68

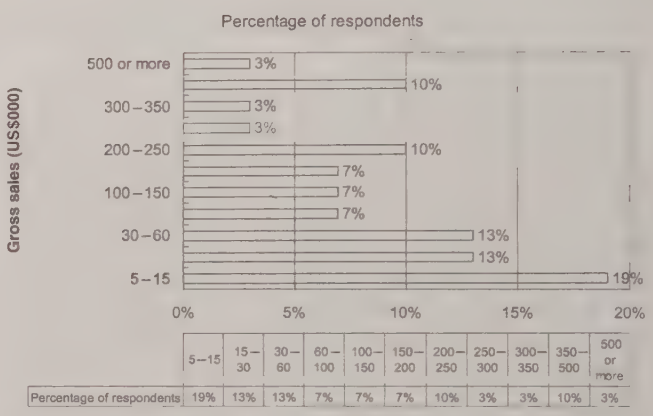

Figure 1. Gross retail sales from all facilities.

Empirical Model

The logit model was selected for the empirical analysis because of its asymptotic characteristic that constrains the predicted probabilities to a range of zero to one. The logit model is also favored for its mathematical simplicity and is often used in a setting where the dependent variable is binary. As the survey utilized in this analysis provided individual rather than aggregate observations, the estimation method of choice was the maximum likelihood estimation (MLE). Among the beneficial characteristics of MLE are that the parameter estimates are consistent and asymptotically efficient (Pindyck and Rubinfeld, 1991).

The model assumes that the probability of observing a specific outcome (i.e., the participant was satisfied with the returns from farmers' market operations), P_i, is dependent on a vector of independent variables (X_{ij}) associated with producer i and variable j, and a vector of unknown parameters β. The likelihood of observing the specific

values of the dependent variable was modeled as a function of variables that included producer characteristics:

$$P_i = F(Z_i) = F(\alpha + \beta X_i) = 1/[1 + \exp(-Z_i)] \quad (1)$$

where:
$F(Z_i)$ = the value of the logistic function associated with each possible value of the underlying index Z_i;

P_i = the probability that a specific outcome is observed (i.e. a producer was satisfied with the returns from farmers' markets) given knowledge of the independent variables X_is;

exp = the base of natural logarithms (2.7182);

Z_i = the underlying index number or βX_i; and

α = the intercept.

In Equation 1, βX_i is a linear combination of independent variables, so that:

$$Z_i = \log [P_i/(1 - P_i)] = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \varepsilon \quad (2)$$

where,
$i = 1, 2, \ldots, n$ observations;

Z_i = the unobserved index level or the log odds of choice for the ith observation;

X_n = the nth explanatory variable for the ith observation;

β = the parameters to be estimated;

ε = the error or disturbance term.

The dependent variable Z_i in Equation 2 represents the logarithm of the odds ratio. The parameter estimates do not directly represent the effect of the independent variables. To obtain the estimators for continuous explanatory variables in the logit model, the changes in probability P_i that $Y_i = 1$ brought about by a change in the independent variable X_{ij}, are given by:

$$(\partial P_i/\partial X_{ij}) = [\beta_j \exp(-\beta X_{ij})]/[1 + \exp(-\beta X_{ij})]^2 \quad (3)$$

For qualitative discrete variables, such as the explanatory variables used in this study, $\partial P_i/\partial X_{ij}$ does not exist. Probability changes are then determined by:

$$(\partial P_i/\partial X_{ij}) = P_i(Y_i = 1{:}X_{ij}) - P_i(Y_i = 0{:}X_{ij}) \quad (4)$$

The following model was developed to predict the likelihood of producer satisfaction with the returns at farmers' markets:

$$\text{PROFIT} = \alpha + \beta_1 \text{ RETAIL} + \beta_2 \text{ RELATED} + \beta_3 \text{ ORGANIC} + \beta_4 \text{ INCFM} + \beta_5 \text{ GROW} + \beta_6 \text{ OWN} + \beta_7 \text{ AGE} \quad (5)$$

where,

PROFIT = 1 if the individual is very satisfied with farmers' market profit margin, and 0 otherwise;

RETAIL = 1 if the individual retailed 70% or more of produce grown, and 0 otherwise;

RELATED = 1 if the individual sold value-added products, and 0 otherwise;

ORGANIC = 1 if the individual sold organic produce, and 0 otherwise;

INCFM = 1 if percentage of gross income coming from farmers' markets was at least 20%, and 0 otherwise;

GROWTH = 1 if the individual's farmers' market business is in the growth stage, and 0 otherwise;

OWN = 1 if the individual is the owner of the farm, and 0 otherwise;

AGE = 1 if the individual was older than 50 years of age, and 0 otherwise.

The dependent variable PROFIT is a binary variable, which takes the value of 1 if the respondent reported to be very satisfied with farmers' market profit margins, and zero if the individual is less than very satisfied. The explanatory variables are based on information drawn from the survey, including demographic and socio-economic background of the producers as well as information on farmers' market and farm characteristics.

The variable RETAIL captures the rate of participation by a farmer in selling directly to consumers as opposed to other selling methods, such as wholesale marketing. Given that the retail prices are always higher than the wholesale prices, and the additional cost of retailing is less than the difference between the retail and wholesale price, the variable RETAIL is expected to have a positive sign. The variable RELATED captures the returns from selling value products such as fruit pies, apple cider, and carved pumpkins. Profit margins on value added products are expected to be higher than those for fresh fruits and vegetables. Therefore, the variable RELATED is expected to have a positive sign. The variable ORGANIC captures whether there is premium price for niche products. Because organic produce is often sold at a premium, the variable ORGANIC is expected to have a positive sign. The variable INCFM was introduced to capture the impact of primarily selling through farmers' markets versus other avenues. The variable GROWTH was introduced to capture the stability of income from direct marketing. A producer who is in a mature stage is expected to have a stable income compared to producers in other stages of business. The variable OWN, captures the impact of vertical integration of owning, producing, and marketing of produce on profit margin satisfaction. The variable AGE was introduced to capture the impact of experience on profit margin satisfaction. A descriptive tabulation of the explanatory variables is listed in Table 2. The variables AGE, RETAIL, and INCFM were defined as discrete rather than continuous because the logit model can capture the point at which these variables contribute significantly towards producer satisfaction with returns from farmers' market related activity.

Table 2. Descriptive tabulation of explanatory variables in Equation 5.

Variable	*N*	Mean	Standard deviation
Percentage of gross income coming from farmers' markets (INCFM)			
Less than 20%[1]	26	0.7222	0.4543
20% and over	10	0.2778	0.4543
Stage of business development (GROWTH)			
Growth	22	0.6111	0.4944
Initial/mature/decline[1]	14	0.3889	0.4944
Do you sell organic produce? (ORGANIC)			
Yes	4	0.1111	0.3187
No[1]	32	0.8889	0.3187
Do you sell value-added products? (RELATED)			
Yes	10	0.2778	0.4543
No[1]	26	0.7222	0.4543
Percent retailed (RETAIL)			
Less than 70%[1]	15	0.4167	0.5000
70% and over	21	0.5833	0.5000
Do you own the farm? (OWN)			
Yes	28	0.7778	0.4216
No[1]	8	0.2222	0.4216
Age (AGE)			
Less than 50 years old[1]	25	0.6944	0.4672
Over 49 years old	11	0.3056	0.4672

[1] Refers to the category that was omitted in the logit analysis.

Table 3. Likelihood of producer satisfaction with the returns from farmers' markets.

Variable	Estimate	Standard error	Change in probability
Intercept	–6.7384	2.7224	–
INCFM	1.4056	1.4332	0.2525
Retail[2]	3.0507	1.5125	0.4115
Related	0.8942	1.4020	0.1520
Organic[2]	5.9277	2.8082	0.8724
Growth[1]	2.7967	1.5003	0.3639
Own	1.5453	1.6919	0.1790
Age[1]	–2.3769	1.3441	–0.2785

Significance of chi-square statistic: 0.02.
McFadden's R^2: 0.37.
Ratio of nonzero observations to the total number of observations: 0.31.
[1] Significant at the 0.10 level.
[2] Significant at the 0.05 level.

Table 4. Logit model prediction success.

		Predicted	
		0	1
Actual	0	19	4
	1	6	7

Number of correct predictions: 26.
Percentage of correct predictions: 72.2.

Results and Discussion

The maximum likelihood estimates and model summary statistics are presented in Table 3, while Table 4 exhibits the extent of prediction success of the model. As can be seen from Table 4, the model correctly predicted the non-occurrence (actual 0, predicted as 0) of the event 19 times and occurrence (actual 1, predicted as 1) of the event 7 times. The model wrongly predicted occurrence as non-occurrence (actual 1, predicted as 0) 6 times and non-occurrence as occurrence (actual 0, predicted as 1) 4 times. Total correct predictions were 26 out of 36. As a result, with a 50–50 classification table, approximately 72% of the producers in the sample were correctly classified as either being very satisfied with the profit margin obtained from farmers' markets or not being very satisfied. The goodness of fit for the regression is given by the McFadden's R^2 of 0.37, which indicates good fit when dealing with survey data. The chi-square statistic rejected the null hypothesis that all explanatory variables were insignificant at the 0.01 level. The ratio of nonzero observations to the total number of observations is 31%. That is, out of 36 observations, the dependent variable PROFIT equaled 1 in 11 observations and 0 in 25 cases.

The coefficient of the variable AGE is statistically significant at the 0.10 level and exhibits a negative relationship with the dependent variable PROFIT. This implies that older farmers' market participants are less likely to be satisfied with the returns from these markets. The estimated marginal effect suggests that producers who

are 50 years of age or older are 28% less likely to be very satisfied with the profit margin obtained from farmers' market operations than their younger counterparts. This result may be indicative of younger farmers' ability to adjust more rapidly to changing consumer tastes and preferences that allow them to take advantage of market trends much faster than their older counterparts. It may also suggest that younger farmers are more efficient in direct-to-consumer retailing compared to older growers, who are generally more accustomed to wholesale markets. In either case, the implication is that long-term profitability and satisfaction with returns from direct marketing is related to willingness to change marketing focus and production to meet customer demand.

The coefficient of the variable ORGANIC is positive and statistically significant, implying that profitability (and hence farmer satisfaction) is enhanced by selling organic products at farmers' markets. The estimated marginal effect suggests that growers who sell organic produce at farmers' markets are 87% more likely to be satisfied with profit margins than those who do not sell such products. This finding is not surprising, given that organic products are generally viewed as 'higher quality products' and organic growers are able to charge a premium for these products. The above finding may also suggest that farmers who are more willing to be innovative in their production and product offering are the ones who are successful in the marketplace. Organic production is one way in which farmers can grow premium specialty products that will command a price premium in the market. Farmers' markets allow producers to combine niche market production/products and direct marketing to further enhance profitability (and farmer satisfaction) and overall farm viability.

The estimated coefficient of the variable RETAIL is positive and statistically significant at the 5% level. This implies that farmers who retail at least 70% of the dollar value of their products are significantly more likely to be very satisfied with their returns from farmers' market operations. Specifically, the estimated marginal effect of RETAIL indicates that producers who retail 70% or more of the value of their products are 41% more likely to be very satisfied with the farmers' market returns than those who retail a smaller proportion of their output through these markets. This finding is consistent with the notion that direct marketing through channels such as farmers' markets allow the producers to capture a greater share of consumer food expenditure by eliminating the share of market intermediaries, such as brokers and wholesalers.

The estimated model coefficients further show that the stage of business growth is an important determinant of profits from farmers' market operations. Specifically, the positive sign of the coefficient of the variable GROWTH suggests that businesses in their growth stage are likely be more profitable than those in other stages of business development. The estimated marginal effect indicates that producers whose farmers' market operations are in the growing stage are 36% more likely to be very satisfied with profit margins than those with operations that are not growing. This may imply that growers are more successful at farmers' markets if they are involved in direct marketing from the early stages of operation.

The empirical results show that farm ownership structure has no effect on the profitability of farmers' market operations, as indicated by the statistically insignificant coefficient of the variable OWN. Similarly, the insignificant coefficients of RELATED and INCFM imply that retailing of value-added products and percentage of gross income coming from farmers' markets do not significantly influence profit satisfaction. The finding that retailing of value-added product has no effect on profitability runs somewhat counter to the often-held view that farmers' income can be enhanced if value-added activities are incorporated with conventional farming operations. One possible explanation of our finding is that the small-scale value-added activities are not really cost-effective and therefore may not be profitable. On the other hand, this result may be due to the small sample size used in the analysis.

Conclusions

Farmers' markets play a vital role in supporting the agriculture in New Jersey and other northeastern states. These markets provide an excellent marketing channel for small producers to sell directly to consumers and realize more favorable prices for their products compared to traditional wholesale markets. Further, these markets allow small-volume producers to directly serve specialized and niche market segments (e.g., customers for organic products), for which the volume is not large enough to support a wholesale market. Consumers also find these markets to be convenient places at which to purchase fresh produce from the growers.

Farmers' satisfaction is an important factor for the growth and future success of the farmers' market. This study identifies the farmer characteristics and farm activities associated with higher profitability and farmer satisfaction from farmers' market operations. The results suggest that farmers' profitability is enhanced through catering to niche markets, such as that for organic products. Similarly, greater utilization of direct marketing (e.g., via farmers' markets) helps increase profit margins and hence farmer satisfaction.

Although the survey found the majority of the farmers participating at farmers' markets to be satisfied with the profit margin, direct retailing to consumers through these off-farm outlets involves considerable investment in terms of labor, time, and equipment. Harvesting, packing, loading, and transporting the products to farmers' market locations are all labor-intensive activities and require a reliable labor supply. Farmers need to be able to sell enough volume to justify the considerable investment in human and physical capital. Continued growth of these

farmers' markets will depend on farmers' ability to sell sufficient quantities of their products at favorable prices.

This study uses profitability from farmers' market operations as the indicator of farmer satisfaction. This measure of business owner/operator satisfaction follows the standard neoclassical theory, where a firm's objective is to maximize its profit. However, such a narrow definition of owner satisfaction is a weakness of the present study. Ideally, studies of owner satisfaction should include not only profitability of business, but other factors as well. Future studies should incorporate financial as well as nonfinancial returns in exploring the issue of farmer satisfaction and its implications for the growth and success of farm businesses.

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Family and seller interactions in farmers' markets in upstate New York

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Abstract. *Farmers' markets promote alternative agriculture by allowing farmers to meet the demand for specialized agricultural products and establish new businesses. Farmers sell at farmers' markets for social and personal, as well as economic, reasons. Successful farmers' marketing involves interactions with customers, but little is known about these interactions. This study aimed to determine what happens when a family shops at farmers' markets, specifically how parents and children interact in the market in relation to each other and to the farmers. Systematic observation was used to follow 22 families with young children. A coding sheet was used to categorize sensory, perfunctory, informational interactions, attempts to influence purchases and additional interactions. Results showed information was more likely to be exchanged between farmers and parents or parents and children. Children were more likely to be involved in sensory interactions. Farmers interact with families through perfunctory interactions or informational interactions, rather than encouraging them to buy specific items. Since some important societal benefits of farmers' markets can only be achieved if information is exchanged during interactions, market managers and outreach professionals should encourage and assist farmers with providing information to customers. Further research is needed to understand why farmers favor social over explicitly sales-focused interactions, which interactive strategies may be optimal to achieve the fullest economic and non-economic benefits for both farmers and customers, and what is the economic and non-economic impact of providing information in the farmers' market.*

Key words: family interactions, family shopping, parent–child interactions, fruits and vegetables, social and economic benefits

Introduction

As a direct form of agriculture, farmers' markets are characterized by bringing farmers and consumers together in a unique social institution. Farmers' markets are beneficial to farmers, consumers, local communities and the environment. They help people re-connect with food, find out about how food is produced and strengthen community identity (Bullock, 2000). Farmers' markets create a context for closer social ties between farmers and consumers, but remain fundamentally rooted in commodity relations (Hinrichs, 2000). Hinrichs raises the question: are farmers' markets primarily social or economic institutions? To understand the interplay between the economic and non-economic functions of farmers' markets, it is helpful to consider farmers' markets from the perspectives of farmers, consumers and civic society.

Farmers' perspective

Farmers' markets provide important outlets for small-scale farmers in the US (Burns and Johnson, 1996; Lyson *et al.*, 1995; Vaupel, 1989). There are now more than 2800 farmers' markets (Agricultural Marketing Service at USDA, 2001; Festing, 1998), and an estimated 19,000 farmers rely solely on farmers' markets to sell what they grow (Agricultural Marketing Service at USDA, 2001). Farmers' markets help farmers economically because they can sell products directly to consumers at retail prices (Festing, 1998; Myers, 1991), receiving substantially greater income per food dollar compared with selling in wholesale markets (Stumbos, 1993). Farmers' markets promote alternative agriculture by allowing farmers to: (1) fill a niche for consumers valuing quality and variety and wishing to support local agriculture; (2) meet demand for specialized and non-standardized foods and agricultural products; (3) establish new marketing businesses; (4) experiment with new products at low risk; and (5) make the transition to larger economic ventures (Hilchey et al., 1995; Lyson et al., 1995; Roth, 1999). Markets help farmers to expand their business, primarily by adding additional venues for direct selling, but also by helping farmers make contacts with local stores, restaurants, wholesale accounts or community-supported agriculture (Feenstra and Lewis, 1999). The benefits that farmers receive are also both economic and non-economic (Hilchey et al., 1995).

Research supports the idea that the social atmosphere of farmers' markets appeals to farmers, in addition to the economic benefits. Farmers' markets are organized as flexible networks that allow for diverse seller motivations,

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products and marketing strategies (Lyson et al., 1995). From a study in upstate New York, the most important reasons that farmers report for selling at farmers' markets are non-economic, i.e., social and personal ('We enjoy visiting with customers and other vendors' and 'We enjoy doing it') as well as economic ('We want extra income' and 'Our other income sources are limited') (Lyson et al., 1995).

Consumers' perspective

Customers have stated that the leading reasons they attend farmers' markets are for freshness of goods, quality and variety of produce, social atmosphere and growing concerns for food safety issues (Just and Weninger, 1997). Farmers' markets allow consumers access to more local produce and they can offer significant savings by cutting out the middle man (Bullock, 2000). In a comparative study of the behavioral ecology of farmers' markets and supermarkets, farmers' markets were perceived by their customers as friendlier, more personal, rural, smaller and happier settings than were the supermarkets by their customers (Sommer et al., 1981).

Children are making more requests in shopping environments and they appear to be emerging players in family decision-making (Anliker et al., 1992; Kraak and Pelletier, 1998; Lackman and Lanasa, 1993; Sommer et al., 1981). They are particularly influential with regard to purchases that involve them directly (Foxman and Tansuhaj, 1988). Through following parents and children in supermarkets, Altman (1995) found that children influenced their guardians' choices of fruits, vegetables and beverages. It has been shown that food experiences early in the life course are prominent in shaping adult current fruit and vegetable choices (Devine et al., 1998). Focus groups with school-age children indicated that increasing availability and enhancing preference for fruits and vegetables would increase their consumption (Baranowski et al., 1993). Farmers' markets may be settings where children make food requests and attempt to influence their parents' purchasing decisions.

Supermarket marketing literature typically concentrates on what purchases parents make when their children make requests (Atkin, 1978; Galst and White, 1976; Isler et al., 1987; Ogden and Ogden, 1993; Wells and Lo Sciuto, 1966). Little attention has been given to the interactions that occur between parents and children, and how children may learn about food in shopping environments, in particular in farmers' markets. Farmers' markets may help parents and children learn about food for three reasons: (1) farmers are present and interact with customers; (2) sensory interaction with the produce occurs and is often encouraged; and (3) the market is informal and interactive in nature (Beckdon et al., 1998).

Civic perspective

Besides the direct benefits to farmers and consumers, farmers' markets benefit society indirectly by bringing together producers and consumers (Lyson et al., 1995). They have strong educative value in putting people in touch with where their food comes from, who grows it, and how it is grown (Bullock, 2000). Farmers' markets benefit the environment because the food sold there requires less processing, packaging and preserving, because it does not have to survive long journeys (Bullock, 2000). Farmers' markets also promote the sale of organic or less intensively grown food because there is less emphasis on high-volume production methods (Bullock, 2000).

Also, farmers' markets are venues that could potentially help increase the consumption of fruits and vegetables (Just and Weninger, 1997). Increased fruit and vegetable consumption has been encouraged to help prevent cancer and cardiovascular disease (Domel et al., 1993; Reicks et al., 1994). Despite the proposed benefits of fruit and vegetable consumption, barriers to consumption exist (Eisner et al., 1992) that include lack of availability, time, knowledge, and effort to prepare, and preference for other foods (Reicks et al., 1994). Farmers' markets can play a role in helping to overcome barriers that the public has to eating more fruits and vegetables. To do so effectively, however, requires that information is exchanged between producers and customers in the markets (Just and Weninger, 1997).

Research aim

These perspectives reinforce that farmers' markets are social institutions with economic and non-economic functions. Self-reports from farmers and customers support the social benefits of farmers' markets, but there is little research in support of the behavior of consumers and farmers in the market being interactive. Given the knowledge that children influence parents' decisions in shopping environments, it is also important to know how the parent–child–vendor triad functions in farmers' markets.

Because little is known about the interactions of farmers and families in farmers' markets, this study used systematic observation to follow families in farmers' markets. This study aimed to determine what happens when a family shops at farmers' markets, specifically how long do families spend in the market, how many vendors do they visit, and how do parents and children interact in the market in relation to each other and to the farmers. Given the dual economic and social characteristics of farmers' markets, we examined if overtly economic or social interactions predominated. We also determined the role that the presence of, and interactions with, the produce has in the market for parents and children.

Methods

In this study, direct observation was used to follow families in farmers' markets, and a coding sheet was used to record the interactions that occurred during the shopping trip. The advantage of using direct observation is that it

provides a highly detailed, nearly complete record of what people do and is not dependent on the respondent's ability to interpret a questionnaire (Wells and Lo Sciuto, 1966). Possible sources of error in systematic observation are reactive effects from being observed, investigator error and biased sampling (Sommer and Sommer, 1991). These sources of error were, in part, controlled by a pilot study, systematic recording of observations using a coding sheet, and minimizing observer involvement in shopping.

Before beginning the study, casual observations had been made in several farmers' markets to determine feasibility. We determined that the ideal market research site was between 15 and 50 vendors, with approximately two-thirds of the vendors selling mostly fruits and vegetables. Sites of this size were large enough to be able to make the necessary observations, but small enough to be able to follow the families.

A coding sheet was developed to categorize interactions and to help the observer quickly write down the actions occurring. Perfunctory, informational, sensory, purchase-influencing attempts and additional interactions were categorized on the coding sheet. For each interaction, the actor was recorded, and for perfunctory and informational interactions, the receiver of the interaction was recorded. These interactions were defined based partly on the definitions of interactions used in Sommer's study of the behavioral ecology of farmers' markets and supermarkets (Sommer et al., 1981).

Perfunctory interactions were defined as acknowledgment of another party or simple conversation. The actor began the interaction, and the person to whom the comment was directed was recorded as the receiver. Examples of perfunctory interactions included, 'How are you?' or 'The weather is nice today.'

Informational interactions were defined as an exchange of information, in particular, with regard to the items in the market. The provider of information was the actor and the receiver was the person to whom the information was directed. Informational interactions might include 'What kind of squash [*Cucurbita* spp.] is this?' or 'Apples [*Malus* spp.] are only in season beginning in September.'

Sensory interactions were defined as actions involving food, and one of three selected senses: taste, touch or smell. Parents and children were the actors recorded for sensory interactions. These were coded as one of the following five actions: touch, pick up, smell, taste, or eat in entirety. Examples of sensory interactions included children picking up produce to examine it, children tasting the produce available, or parents eating produce bought. 'Tasted' items were foods eaten, but not bought. Perhaps the farmer invited the customer to sample produce, or a child helped himself to a bite. Those items that were 'eaten' were foods purchased and consumed during the shopping trip.

Attempts to influence purchases were coded as initiated by the child, parent or farmer. Child-influencing attempts were identified when a child asked, pleaded, pointed or grabbed, bargained or used other means to influence a parent's purchasing. The parental response to each request was recorded as either agreement or disagreement, based on whether or not the item was purchased immediately after the request. Parent-influencing attempts were defined as a parent inviting or suggesting that a child make a selection for purchase. Farmer-influencing attempts were defined as farmers initiating or suggesting a purchase selection.

All interactions that did not qualify as perfunctory, informational, sensory or purchase-influencing attempts were coded as additional interactions. Examples of additional interactions were the child looking at the observer, the farmer talking to the observer, or the family talking to other customers in the market.

In this study, an 'episode' was defined as a family stopping in front of a vendor booth with an apparent consideration to buy something. Episodes began when a family stopped at a vendor, and ended when the family left the vendor booth or table. The interaction that began the episode was recorded as the first interaction. A 'between-episode' was defined as the time a family spent between vendors browsing the market, walking in the aisles, or looking at produce or products, with no intention of buying them.

Using the categories of interactions listed above, a preliminary coding sheet was developed. This coding sheet was used during a pilot study to help test the reliability of the coding sheet and feasibility of the study. Two observers followed the same families and recorded their interactions on the preliminary coding sheet as the families shopped in the farmers' market. The interactions recorded on the coding sheets were comparable and key phrases and descriptions of family events were coded similarly on the coding sheet.

The study was conducted over the course of 8 weeks and took place at three different farmers' markets, one rural and two urban. These markets were typical of those in upstate New York. The observer went to the market during market hours and recruited families to participate in the study as they arrived in the market. Families were approached and asked for permission to be followed by a researcher while they shopped in the farmers' market. The researcher explained that the family would not be disturbed in any way during shopping. Families were not told why they were being followed. Before the families began shopping, the ages of the children present were asked of the adults present.

At least one adult present in a family had to be either a parent or grandparent. Families with more than three adults or three children were excluded. Families with children that looked between the ages of 2 and 12 years were asked to participate, but young children were particularly targeted because of our interest in possibly applying the results to the population of families with children under the age of five who are served by federal and state nutrition assistance programs. Families with children in strollers were generally not selected, but if one child could move freely about the market, then a family with a stroller was not excluded.

During the shopping trip, the interactions that occurred were recorded on the coding sheet. After a family left the market, the interactions were reviewed and episodes and between-episodes were recorded. The episodes and between-episodes were coded by hand. Databases of the interactions and family background information were created using SPSS 10.0 (SPSS Inc., 1999).

Results

Thirty-one families were asked to participate in the study. Of these, 22 families agreed to participate and were followed. Fourteen (63.6%) families appeared to be European–American and eight (36.4%) appeared to be racial-ethnic minorities.

Of the 22 families followed, 12 (54.5%) had the mother as the only adult present. Both father and mother were present in three families (13.6%), mother and grandmother in three (13.6%), only grandmother in two (9.1%), grandmother and aunt in one (4.6%), and mother, grandmother and an adult child in one (4.6%). There were a total of 35 children represented in the 22 families. One child was present in 10 (45.5%) of the families, two children in 11 (50.0%), and three children in one (4.5%) family. The mean age of the children was 4.3 years. The children ranged in age from 2 to 9 years.

Typical market visit

Families averaged 15.6 minutes per market visit overall. The minimum visit to the market was 2 min and the maximum visit was 35 min. Families averaged six episodes per market visit, with a minimum of one episode and a maximum of 16 episodes. Families averaged three between-episodes per visit, with a minimum of zero and maximum of seven between-episodes.

Episodes

Families averaged five interactions per episode, with a minimum of one and maximum of 11. Based on the time spent in the market and total episodes or between-episodes per family, the average time per episode or between-episode was about 2 min.

Sensory interactions began about 30%, and informational interactions about 24%, of the 127 episodes that occurred (Table 1). The least frequent first interaction in an episode (2.4%) was a farmer's attempt to influence purchase.

Interactions in the farmers' market

A total of 586 interactions were recorded of seven different categories: perfunctory, informational, sensory, attempts to influence purchases by the child, parent or farmer, or additional. Perfunctory and sensory interactions each made up slightly less than 25% of the 586 interactions (Table 2). Farmer attempts to influence purchase comprised only 2% of the 586 total interactions and occurred the least often.

Across all interactions, of the items available in the market, vegetables were involved in 24.4%, fruits in 20.5%, and foods other than fruits and vegetables in 18.9% of all interactions (Table 2). Vegetables were twice as likely to be involved in an informational interaction than were fruits.

Perfunctory interactions. The parent was most frequently the actor in perfunctory interactions, totaling more than half of perfunctory interactions recorded (Table 3). Perfunctory interactions were most often with the parent as

Table 1. First interactions for episodes.

Interaction category	First interaction for an episode	
	Frequency	Percentage
Perfunctory	23	18.1
Informational	30	23.6
Sensory	37	29.1
Child-influencing attempt	15	11.8
Parent-influencing attempt	15	11.8
Farmer-influencing attempt	3	2.4
Additional	4	3.2
Total	127	100.0

Table 2. Distribution of interactions, and the market items involved in the interactions.

Interaction category	Item						
	Fruit	Vegetable	Food	Other	No item	Total	Percentage
Perfunctory	15	21	25	11	72	144	24.6
Informational	24	41	18	18	16	117	20.0
Sensory	33	54	33	21	–	141	24.1
Child-influencing attempts	31	18	20	9	–	78	13.3
Parent-influencing attempts	14	3	12	6	–	35	5.9
Farmer-influencing attempts	3	6	3	1	–	13	2.2
Additional	–	–	–	–	58	58	9.9
Total	120	143	111	66	88	586	100.0
Percentage	20.5	24.4	18.9	11.3	24.9	100.0	

Table 3. Actor and receiver of perfunctory and informational interactions.

Actor	Receiver	Interactions			
		Perfunctory		Informational	
		Frequency	Percentage	Frequency	Percentage
Parent to	Parent	7	4.9	6	5.1
	Child	53	36.8	36	30.8
	Farmer	17	11.8	7	6.0
	Self	4	2.8	0	0.0
Child to	Parent	17	11.8	23	19.7
	Child	3	2.1	1	0.8
	Farmer	3	2.1	2	1.7
	Self	1	0.6	0	0.0
Farmer to	Parent	21	14.6	38	32.5
	Child	16	11.1	3	2.6
Other		2	1.4	1	0.8
	Total	144	100.0	117	100.0

actor and child as receiver (36.8%). The farmer was actor in approximately 25% of perfunctory interactions, with the farmer directing most of these interactions to the parent.

Informational interactions. The farmer as actor and parent as receiver was the most frequent informational interaction recorded (Table 3). Parent as actor and child as receiver was the second most frequent informational interaction, making up slightly less than one-third of informational interaction. Farmer as actor and parent as receiver made up 32.5% of the informational interactions, whereas farmer to child interactions were only 2.6% of informational interactions.

Sensory interactions. Fifty-four of the 141 sensory interactions involved vegetables, the most frequent of all items in the market (Table 2). Fruits were involved in 33 of the 141 sensory interactions. Items were most often picked up (44.0%), eaten (22.0%), touched (19.9%), tasted (10.6%) or smelled (3.5%).

Children were the actors in 91 (two-thirds) of the 141 sensory interactions. Of these 91 interactions, 11 interactions involved children tasting items and 27 involved children eating items. Children tasted grapes (*Vitis* spp.) on four separate instances, and blackberries (*Rubus* spp.), prunes or snow peas (*Pisum sativum* L.) each once. Four interactions involved children tasting foods other than fruits and vegetables. Eleven interactions had children eating fruits, specifically, apples (1), bananas (*Musa sapientum*) (2), blackberries (2), peaches (*Prunus persica*) (1), plums (*Prunus* spp.) (4) and cherries (*Prunus* spp.) (1). Children ate foods other than fruits and vegetables 16 times.

Parents were the actors in the other 50 sensory interactions. Four interactions involved parents tasting items in the market and four involved parents eating items. Three of the interactions were parents tasting foods other than fruits and vegetables and one interaction involved a parent tasting a snow pea. Three were parents eating foods other than fruits and vegetables and one involved a parent eating a plum.

Attempts by children to influence purchases. Seventy-eight interactions were attempts by children to influence purchases (Table 2). Fruits and vegetables were involved in 49 of these attempts. Most child-influencing attempts were for fruits (39.7%), followed by foods other than fruits and vegetables (25.7%), vegetables (23.1%) and finally other items (11.5%). Of the 78 child-influencing attempts, 21 resulted in an immediate purchase by the parent (27%). Of the 49 attempts for fruits or vegetables, an immediate purchase was made 16 times (32.7%). Of the 29 attempts for food or other items in the market, an immediate purchase was made 5 times (17%).

Over half of the child-influencing attempts involved children asking their parents for items in the market. A little more than one-third of child-influencing attempts involved children pointing to or grabbing items in the market. About 10% of child-influencing attempts involved children pleading or fussing over an item in the market.

Attempts by parents to influence purchases. Thirty-five interactions were attempts by parents to influence purchases (Table 2). Most parent-influencing attempts were for fruits (40.0%), followed by foods other than fruits and vegetables (34.3%), other items (17.1%) and vegetables (8.6%). An immediate purchase was made after 27 of the 35 parent-influencing attempts (77.1%).

Attempts by farmers to influence purchases. Thirteen interactions were attempts by farmers to influence purchases (Table 2). Farmers-influencing attempts were most frequently for vegetables (46.2%), followed by fruits (23.1%) and other foods (23.1%), and finally other items (7.7%). Five of these 13 interactions resulted in an immediate purchase.

Additional interactions. Additional interactions were defined as any interaction that did not qualify as perfunctory, informational, sensory or purchase-influencing

attempt. The observer was involved in 29 of the 58 additional interactions, half of additional interactions and about 5% of all 586 interactions (Table 2). The child looking at the observer was the most frequent additional interaction.

Discussion

Based on the observations of the farmer and family interactions, farmers' markets provide the opportunity for using several senses, actively involving the customer. The market is interactive and a variety of interactions occurred, including sensory, perfunctory, informational and requests for purchases. There were instances of three different types of sensory interactions, i.e., smelling, touching and tasting products in the market. Across all interactions, perfunctory and sensory interactions occurred the most frequently.

Family visits to the farmers' markets are typically short, averaging approximately 15 min. These results are similar to those of Sommer et al. (1981), whose data showed that the length of time people spent in the market averaged approximately 10 min per shopping trip. Families stopped at an average of six vendors, although the average size of the markets was 15–50 vendors. This shows that, in general, people do not linger in the market and decisions are made quickly.

Based on the average time per episode or between-epsiode, farmers have about 2 min and five interactions with a customer to sell their goods. The least frequent initial interaction was attempts by farmers to influence purchases. The small frequency of farmers initiating an episode by inviting a purchase possibly implies that farmers do not actively invite purchases to be made. More often, sensory interactions initiated episodes, and families were drawn to sensory qualities first. Sensory interactions were most likely to initiate an episode (30%), but only 25% of all interactions were sensory. There is no way to infer what effect price has on initial interactions.

Perfunctory and informational interactions

When the farmer is the actor and parent receiver, the exchange is more likely to be informational, whereas when a child is the receiver, the exchange is more likely to be perfunctory. Thus, when information was exchanged in farmers' markets, it was more likely to be exchanged between farmers and parents or parents and children. Rarely did farmers provide information directly to children.

Sensory interactions

Children were most likely to be involved in sensory interactions. Despite vegetables being involved in the most interactions overall, children ate only fruits, i.e., there were no instances of children eating vegetables. Compared to children, parents ate or tasted fewer fruits and vegetables.

Attempts to influence purchases

Children were much more likely to attempt to influence purchases than parents. More than half of children's attempts to influence purchases involved children verbally asking for items, versus pointing or grabbing, pleading or bargaining. In the markets that were selected because they sold predominantly fruits and vegetables, children requested fruits most often, followed by other foods. In over 75% of the cases parents did not purchase the item immediately after it was requested. Parents were twice as likely to agree to purchase fruits or vegetables when compared to food or other items in the market. It appears that children were not influential in immediate purchasing decisions. Several factors may have contributed to the denied requests. Parents may not have heard the requests, they may have already decided to purchase the requested item, or they may have decided to ignore the request for an unknown reason.

Attempts by parents to influence purchases are important to note because parents most often invited children to buy fruits. These invitations more often resulted in a purchase than child-initiated requests.

Farmer-initiated invitations for purchase were few and only accounted for 2% of all interactions. Farmers interact with families through perfunctory interactions or informational interactions, rather than encouraging them to buy specific items.

Study limitations

There are several limitations in doing this type of research. Most important, the presence of an observer may be intrusive, alter behavior or bias results. Five percent of the 586 total interactions involved the observer, despite efforts to remain unobtrusive. These interactions most often involved children looking at the observer, farmers talking to the observer, or parents talking to the observer. The market conditions made it a difficult place in which to make observations. Many people wandered among small aisles and the noise level was a problem at times.

Although the coding sheet was a useful and effective tool to record interactions quickly and efficiently, there were limitations in recording everything. When the researcher looked down at the coding sheet to write down an interaction, some sensory interactions that might have occurred quickly and silently may not have been seen.

Nine families that were asked to participate declined. Families stated various reasons for declining to participate. The refusals may have added some bias to the results that were obtained if the nature of the interactions in these families was different from those observed.

Implications

This study reveals the importance of sensory experience in human connection to food and agriculture. Sensory

interactions were most likely to initiate an episode. The sensory exposure to foods that occurs in farmers' markets may increase familiarity with foods, especially in children. Perhaps children's exposure to fruits and vegetables in farmers' markets may increase attempts to influence purchases of these items, not only in farmers' markets but also in other market settings. Farmers might increase sales by explicitly encouraging sensory interactions, e.g., having an attractive booth to draw in customers.

In this study, farmers gave most information to parents and rarely gave information directly to children. Farmers rarely invited families to make purchases. Knowing this might help farmers better promote their products, in particular to children. If farmers see themselves as providers of information about fruits and vegetables to children, they may be more proactive with them.

Farmers' markets should be encouraged as places of learning and exposure to fruits and vegetables. Parents could use the produce available to teach their children about fruits and vegetables. Children ate and tasted fruits and vegetables much more than their parents. If parents were to consume more fruits and vegetables in the market, they might, by example, encourage their children to do the same. In this study, most of the requests children made in the farmers' market did not result in an immediate purchase. Parents could use the requests children are making as a means to teach their children about the fruits and vegetables they are requesting. Paying close attention to children's requests might increase exposure to, and consumption of, different fruits and vegetables, and might encourage children to request these foods in other shopping environments.

Since the late 1980s, farmers' markets have been used as locations for programming to increase fruit and vegetable consumption among clients in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) (Anliker et al., 1992). The Farmers' Market Nutrition Program gives food coupons to families in WIC to be used at farmers' markets to buy locally grown fresh produce. The program is intended to benefit both farmers and clients. Three benefits of the program to clients are possible: (1) increased fresh fruit and vegetable consumption; (2) increased valuation of fruit and vegetable consumption through information; and (3) increased purchasing power by diverting money that would otherwise be spent on fruits and vegetables (Just and Weninger, 1997). Knowing what families do, or how they interact when they shop in farmers' markets, could help nutrition professionals encourage the use of the Farmers' Market Nutrition Program and develop new interventions that use the farmers' market. Further research should be conducted to see if and what children are learning in the farmers' market. Perhaps interventions could be developed that specifically promote farmer and family interactions in the market, such as recipe cards, or posting questions in vendor booths such as 'Ask me how to cook a squash'. These interventions could encourage parents to seek information from farmers, and also encourage and enable farmers to provide information. By treating farmers' markets not just as places to buy food, but as places where information is exchanged, nutrition professionals can teach customers in markets about foods, encourage consumption of fruits and vegetables, and, in turn, assist farmers to achieve the personal, social and economic benefits that they seek in selling at farmers' markets.

That farmers rarely explicitly invited families to make purchases is somewhat surprising, but is consistent with the reasons that farmers have given for selling at farmers' markets. The two most important reasons found by Lyson et al. (1995) were social and personal (i.e., enjoyment of interactions with customers and other farmers, and of selling in the market environment) rather than economic. It may be, therefore, that the nature of farmer–family interactions is simply a reflection of the underlying primary orientation that farmers have for selling in the farmers' market. It also may be that farmers', whether consciously or unconsciously, have chosen what they believe is the optimal strategy for selling in the farmer's market (i.e., favoring social over explicitly sales-focused interactions). On the other hand, perhaps there are interactive strategies that farmers may employ to maintain the social interactions that they value while, at the same time, increasing sales-focused interactions and ultimately sales. Further research is needed to understand why farmers interact with customers in the way that they do, what interactive strategies may be optimal for farmers' markets to achieve the fullest economic and non-economic benefits for both farmers and customers, and what is the economic and non-economic impact of providing information in the farmers' market.

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Mechanical versus herbicidal strategies for killing a hairy vetch cover crop and controlling weeds in minimum-tillage corn production

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Abstract. *The development of production systems that provide the benefits of reduced tillage and also reduce or eliminate herbicide inputs presents a challenge to practitioners of sustainable agriculture. This research was conducted to evaluate management approaches for minimum-tillage corn production in a hairy vetch cover crop, specifically, mechanical versus herbicidal methods for pre-plant cover-crop kill and for post-emergence control of emerged weeds. Pre-plant treatments included 2,4-D [(2,4-dichlorophenoxy)acetic acid] plus residual herbicides, 2,4-D alone, flail mower, corn stalk chopper, light disk and heavy disk. The pre-plant herbicide treatments were followed by a post-emergence treatment of dicamba, whereas the pre-plant mechanical treatments were followed by post-emergence cultivation, as needed, for weed control. The mechanical treatments that kept residue on the soil surface (mower, stalk chopper and light disk) killed hairy vetch when it was flowering, but not when vegetative. The herbicide treatment with pre-plant 2,4-D alone, followed by dicamba post-emergence, controlled annual broadleaf weeds (the dominant species in these experiments) similarly to treatment with 2,4-D plus residual herbicides, suggesting that residual herbicides may be eliminated in cover-crop-based no-tillage systems. The pre-plant mechanical treatments followed by cultivation did not control annual broadleaf weeds as well as herbicide treatments, but did maintain final populations below threshold levels in two of four experiments. The stalk chopper and light disk left high levels of vetch residue on the soil surface, and reduced initial broadleaf weed populations compared with the heavy disk that incorporated residue. However, broadleaf weed populations were reduced with less efficiency by cultivation of untilled soil following the stalk chopper or light disk (38–69%) than by cultivation of tilled soil following the heavy disk (87–95%). Thus, although maintaining surface cover-crop residue without tillage initially reduced weed emergence, it also reduced the efficiency of cultivation, leading to similar final weed populations in all mechanical-based, pre-plant treatments.*

Key words: cultivation, integrated weed management, organic farming, smooth pigweed, sustainable agriculture, weed survival

Introduction

Cover crops have the capacity to influence many facets of production systems, including the fertility, quality, radiation exchange, moisture and erosion of soils, as well as weed and pest populations (Sustainable Agriculture Network, 1998). In sustainable production systems, it is well established that legume cover crops can be particularly beneficial to high-nitrogen (N) requiring crops such as corn (*Zea mays* L.), by fixing N and reducing the need for off-farm N inputs. For example, Decker et al. (1994) established that a hairy vetch (*Vicia villosa* Roth) cover crop could reduce N requirements for corn production in Maryland. In addition, hairy vetch residue on the surface of soils benefitted no-tillage corn production, by maintaining soil moisture during periods of drought (Clark et al., 1995). Production was most consistent when hairy vetch was killed before planting, rather than after planting or after corn emergence (Teasdale and Shirley, 1998). Current recommendations for minimum-tillage corn with a cover crop rely on herbicides to kill the cover crop before planting and to control weeds emerging after planting. However, there is a need to develop systems with the benefits of minimum-tillage production with cover crops, but which reduce or eliminate the use of herbicides. Organic field-crop producers would benefit from such a system, since they have identified weed management, as well as tillage systems and soil conservation, among their top ten research priorities (Walz, 1999).

Cover-crop residue can influence biological activity at the soil surface, including the suppression of weed

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emergence (Sustainable Agriculture Network, 1998). The density of emerging weeds is inversely related to the amount of residue present (Teasdale and Mohler, 2000). Specifically, mulch area index and solid volume fraction are the best mulch properties for predicting weed emergence through a variety of mulch types (Teasdale and Mohler, 2000). The success of weed emergence through mulches is associated with larger seed size; small-seeded broadleaf weeds are most sensitive to suppression. Despite suppression of weed emergence, cover-crop residue alone cannot reliably provide full-season weed control (Teasdale et al., 2003). Cover crops must be part of an integrated weed management system to achieve consistent, long-term weed control (Williams et al., 1998).

Mechanical cultivation of weeds has been practiced primarily in plowed soils, but equipment has recently been developed for cultivation in no- or minimum-tillage systems. Cultivation, alone, often does not provide adequate weed control, but the combination of cultivation plus banded herbicide in the crop row has controlled weeds and permitted production of crop yields equivalent to those obtained with broadcast herbicides (Buhler et al., 1994, 1995; Hanna et al., 2000; Hartzler et al., 1993; Mulder and Doll, 1993; Mt. Pleasant et al., 1994). Banding herbicide is required for optimum weed control, because weeds growing within the row are difficult to disturb using mechanical methods, particularly in minimum-tillage systems. In-row weeds must be controlled by burying seedlings with soil moved from the area between rows; however, this can only be done effectively if there is a size differential between crop and weed (Mohler, 2001). The ecological basis for this differential is faster emergence and absolute growth rate of crops, due to the larger seed reserves of crop, relative to weed seeds. However, this may be compensated for by the faster relative growth rate of weed, compared to crop plants, as well as by possible environmental conditions that favor weeds more than the crop. If weeds become too large for adequate burial before the crop reaches sufficient size to withstand aggressive soil movement into the row, mechanical cultivation will fail to control these weeds.

An integrated system, using both cover crops and mechanical cultivation, could improve weed control in comparison with reliance on either strategy alone. Liebman and Gallandt (1997) propose that successful integrated weed management systems can be developed without herbicides by combining several strategies or 'little hammers' that would cumulatively reduce the relative fitness of weeds versus crop. Although not sufficient to provide full-season weed control alone, cover-crop residue may suppress early emergence of weeds sufficiently to reduce in-row weed populations that can be problematic for cultivation-based systems. Thus, if cover crops can be killed, and escaped weeds adequately controlled, using mechanical means, an effective reduced-tillage system without herbicides could be developed. These experiments were conducted to evaluate an integrated strategy for corn production in a hairy vetch cover crop with mechanical, versus herbicidal methods for: (1) pre-plant cover-crop kill; and (2) post-emergence control of emerged weeds.

Materials and Methods

Research was conducted on production fields of the Beltsville Agricultural Research Center, Beltsville, MD, using separate fields in 1997, 1998 and 1999. All fields contained combinations of Elkton (fine-silty, mixed, active, mesic Typic Endoaquults), Keyport (fine, mixed, semi-active, mesic Aquic Hapludults), and Matawan (fine-loamy, siliceous, semi-active, mesic Aquic Hapludults) silt loam soils. Hairy vetch had been planted at 28 kg ha^{-1} in September of the preceding year, following harvest of corn for silage. In spring, hairy vetch was killed, either while vegetative during early May, or while reproductive in late May. Early kill dates were: May 7–9 in 1997, April 28–30 in 1998 and May 2–3 in 1999. Late kill dates were: May 23–28 in 1997 and May 26 in 1998 and 1999. Corn was planted with a no-tillage planter within 1 week after the killing operations, except for the early kill date in 1998, when wet weather delayed planting for 3 weeks.

Five treatments were used for killing hairy vetch each year. Treatment 1 was a mixture of 0.56 kg acid equivalent ha^{-1} of 2,4-D [(2,4-dichlorophenoxy)acetic acid], 0.53 kg active ingredient (a.i.) ha^{-1} of paraquat (1,1′-dimethyl-4,4′-bipyridinium ion), 1.8 kg a.i. ha^{-1} of atrazine [6-chloro-*N*-ethyl-*N*′-(1-methylethyl)-1,3,5-triazine-2,4-diamine], 2.2 kg a.i. ha^{-1} of metolachlor [2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl) acetamide], and 0.25% nonionic surfactant. Treatment 2 was 0.56 kg ha^{-1} of 2,4-D. Treatment 3 was flail mowed (model 144BM, 3.6 m width, Loftness Specialized Farm Equipment, Hector, MN) in 1997 but, because this treatment was ineffective, a Buffalo Stalk Chopper (model 52000430, 3.0 m width, Fleischer Manufacturing Inc., Columbus, NE), with cutters set at the most aggressive angle, was used in 1998 and 1999. Treatment 4 was slicing vetch with a light disk (3.6 m tandem disk, Ford Motor Co., Dearborn, MI) set to skim over the surface of the vetch vines and minimize burial of the residue. Treatment 5 was incorporation of vetch with a heavy disk (5.5 m tandem disk, Krause Corp., Hutchinson, KA). Because of continuous rain after the early kill operations in 1998, treatments 4 and 5 required another disking before planting corn. Rotary hoeing (model 1815MT, 4.6 m width, M & W Gear Co., Gibson City, IL) was performed on treatments with exposed soil, shortly after planting corn in 1997 and 1998, but dry weather after planting in 1999 precluded the need for rotary hoeing. Hairy vetch cover ratings were made after planting and rotary hoeing operations were completed by visually estimating the percentage of soil covered by residue.

Each treatment received post-emergence weed management operations when broadleaf weed emergence exceeded

2.3 plants m^{-2}, the threshold level for corn recommended by the University of Maryland IPM Program (undated scouting manual). Post-emergence operations consisted of application of 0.28 kg a.i. ha^{-1} of dicamba (3,6-dichloro–2-methoxybenzoic acid) in treatments 1 and 2, and cultivation with a minimum-tillage cultivator in treatments 3–5. Cultivation was performed with a Krause High Residue Row Crop Cultivator (model 4704-R3 four-row cultivator with 36 cm sweeps, Krause Corp., Hutchinson, KA), except for the first cultivation of untilled soil, which was performed with a Buffalo Cultivator (model 64000430 four-row cultivator with 36 cm sweeps, Fleischer Manufacturing Inc., Columbus, NE). Cultivations were not initiated until corn reached approximately the fourth leaf stage and could sustain some soil movement into the row.

The 1997 experiment was a preliminary exploration of these treatments; consequently, visual estimation of weed cover on September 1 was the only weed data collected. A more intensive collection of weed data was included in the 1998 and 1999 experiments. Weed density was determined approximately once a week, in five 1-m^2 areas within the middle six rows of each 12-row plot, until corn canopy closure. Just before cultivation of selected plots from treatments 3–5, smooth pigweed (*Amaranthus hybridus* L.) plants of different sizes, within 8 cm of the corn row, were identified with plastic labels, color-coded by size. There were 20 smooth pigweed plants within each size group per plot. Approximately 1 week after cultivation, surviving plants at each label were recorded. An experimental unit consisted of the fraction of surviving plants for each 20-plant set. Because of severe drought after weed establishment in 1998 and 1999, corn and weed growth were severely stunted and, unfortunately, no meaningful biomass or yield data could be collected. Therefore, this paper focuses on treatment effects on weed emergence and establishment which occurred before drought conditions became severe.

Treatments were arranged in a split-plot design having four replications, with time of vetch kill as the whole plot and method of vetch kill as the subplot. Subplots were 9.2 m wide and 20, 30 and 18 m long in 1997, 1998 and 1999, respectively. A log transformation was applied to all weed cover and density data to equalize variance before conducting analysis of variance. Means were backtransformed for presentation. Regression analysis was performed on weed survival data, with fraction of surviving weeds as the dependent variable and weed height as the independent variable. Survival data from all treatments at both planting dates in both years were pooled because a similar response was observed across all of these factors.

Results

Hairy vetch management

The soil coverage by hairy vetch residue, and the degree of hairy vetch kill, depended on year, pre-plant operation and timing of pre-plant operations (Table 1). At least 95% of the soil area was covered with desiccated hairy vetch residue following both herbicide treatments, with the exception of the early kill date in 1998. Decomposition of hairy vetch during a rainy 3-week period between hairy vetch kill and corn planting accounted for the lower groundcover seen after early kill in 1998 than in the other years.

The flail mower did not kill hairy vetch when treated in the vegetative stage (Table 1), permitting a dense network of hairy vetch vines to regrow from prostrate stems. These

Table 1. Percentage of the soil covered by hairy vetch residue after pre-plant operations.

		Hairy vetch residue cover (%)[1]		
Stage[2]	**Pre-plant treatment**	**1997**	**1998**	**1999**
Vegetative	2,4-D + paraquat + atrazine + metolachlor	95 (1)	70 (6)	95 (2)
	2,4-D	95 (3)	79 (4)	98 (2)
	Mow	84 (2)[3]	–	–
	Chop	–	66 (2)[3]	95 (3)[3]
	Light disk	44 (3)	5 (0)	92 (4)[3]
	Heavy disk	5 (1)	0 (0)	9 (4)
Flowering	2,4-D + paraquat + atrazine + metolachlor	97 (1)	100 (0)	99 (1)
	2,4-D	99 (0)	100 (0)	98 (1)
	Mow	95 (0)	–	–
	Chop	–	100 (0)	97 (1)
	Light disk	66 (2)	98 (3)	96 (1)
	Heavy disk	29 (2)	16 (1)	18 (3)

[1] The standard error of the mean is shown in parentheses.
[2] Operations were conducted when hairy vetch was vegetative (early May) or flowering (late May).
[3] More than 60% of hairy vetch was live. Hairy vetch in all other treatments was predominantly desiccated residue.

vines covered corn plants and became entangled in cultivator equipment, making it impossible to effectively cultivate this treatment. The flail mower killed hairy vetch and provided high residue cover when hairy vetch was treated at flowering (Table 1). However, final weed cover was higher in this treatment than all others in the 1997 late planting (Table 2), probably because the shredded hairy vetch residue resulting from flail mowing decomposed faster than residue left by the other treatments. Consequently, this treatment was discontinued after 1997, and was replaced with a corn stalk chopper that rolled over hairy vetch, but left it intact. The stalk chopper killed only flowering hairy vetch, but left high residue levels (Table 1). Mowing and rolling during the vegetative stage have been shown to be ineffective for killing several cover crops in several investigations (Creamer and Dabney, 2002).

The light disk was set too aggressively during early operations in 1997 and 1998, resulting in good kill but burial of over half of the hairy vetch residue (Table 1). Heavy rain on bare soil following disking in 1998 required a second operation, which reduced residue cover to a very low level. The light disk was set less aggressively in 1999, resulting in high residue cover but failure to kill vegetative hairy vetch. The light disking killed hairy vetch when performed at flowering in all years, and provided greater than 95% residue cover in 1998 and 1999 (Table 1). The heavy disk incorporated most residue at both stages in all years.

Table 2. Percentage of the soil covered by weeds, primarily yellow foxtail [*Setaria glauca* (L.) Beauv.], on September 1 of the 1997 experiment.

	Weed cover (%)[1]	
Pre-plant treatment	**Early planting**	**Late planting**
2,4-D + paraquat + atrazine + metolachlor	2 b	2 c
2,4-D	1 b	2 c
Mow	41 a	29 a
Light disk	65 a	12 b
Heavy disk	32 a	13 b

[1] Values followed by the same letter in the same column are not significantly different ($P = 0.05$).

Weed management

Annual broadleaf weeds and yellow nutsedge (*Cyperus esculentus* L.) combined to make up 82% and 93% of the total weeds emerging in the early and late planted 1998 experiments, respectively. Annual broadleaf weeds made up 93% and 82% of the weeds emerging in the early and late planted 1999 experiments, respectively. Therefore, presentation of weed populations will focus on annual broadleaf and yellow nutsedge populations in 1998, and annual broadleaf populations in 1999. Smooth pigweed was the dominant annual broadleaf species in both years.

Annual broadleaf weeds emerged in higher numbers following pre-plant treatment with a heavy disk that buried residue, than following other pre-plant treatments that left hairy vetch residue on the soil surface (see earliest population assessment date in Tables 3–6). The light disk in the early 1998 experiment left little residue on the soil surface (Table 1), permitting similar broadleaf weed emergence as that observed in the heavy disk treatment (Table 3). These results agree with earlier research that shows small-seeded broadleaf weeds to be sensitive to suppression by cover-crop residue (Teasdale and Mohler, 2000). Yellow nutsedge, with larger tuber reserves to sustain emergence, was not affected by the presence or absence of hairy vetch residue (see the earliest population assessment date in Tables 3 and 4). The metolachlor component of the pre-plant herbicide treatment was probably responsible for lower yellow nutsedge populations in the late 1998 planting (Table 4).

Sufficient weed populations developed in all treatments (except the late 1998 pre-plant treatment that included atrazine and metolachlor) to require a post-emergence weed control treatment. In the mechanical treatments, weed populations usually exceeded the threshold levels at the

Table 3. Effect of pre-plant hairy vetch management and post-emergence weed management on populations of annual broadleaf weeds and yellow nutsedge during the 1998 early planted crop.

		Annual broadleaf population (number m^{-2})[1]			Yellow nutsedge population (number m^{-2})[1]		
Pre-plant treatment	**Post-emergence operation**	**6/22**	**7/6**	**Percent reduction[2]**	**6/22**	**7/6**	**Percent reduction[2]**
2,4-D+ paraquat + atrazine + metolachlor	Dicamba on 6/26	1.0 c	0.04 c	96	3.7 a	5.2 b	+42
2,4-D	Dicamba on 6/26	4.9 b	0.59 b	88	6.9 a	15.2 a	+119
Light disk	Cultivation on 6/22	10.4 ab	1.92 a	82	6.8 a	5.2 b	24
Heavy disk	Cultivation on 6/22	13.3 a	1.72 a	87	6.2 a	2.7 b	56

[1] Values within columns followed by the same letter are not significantly different ($P = 0.05$).
[2] Reduction of weed density on July 6 relative to that on June 22 by post-emergence operations on June 22 or 26.

time corn reached the four-leaf stage and became large enough for cultivation. In both plantings in 1999, weeds exceeded the threshold sooner in the heavy disk than in the other treatments (Tables 5 and 6), but corn also developed faster in the heavy disk treatment. As a result, corn was at the same leaf stage (approximately four leaves) when all mechanical treatments exceeded threshold weed levels. The only exception was the late 1998 planting, where weed emergence on June 22 exceeded the threshold when corn was only in the two- to three-leaf stage. In this situation, the soil previously tilled by the heavy disk permitted an early cultivation without disrupting the small corn plants;

Table 4. Effect of pre-plant hairy vetch management and post-emergence weed management on populations of annual broadleaf weeds and yellow nutsedge during the 1998 late planted crop.

		Annual broadleaf population (number m^{-2})[1]				Yellow nutsedge population (number m^{-2})[1]			
Pre-plant treatment	**Post-emergence operation**	**6/22**	**6/29**	**7/13**	**Percent reduction[2]**	**6/22**	**6/29**	**7/13**	**Percent reduction[2]**
2,4-D+ paraquat + atrazine + metolachlor	None	0.0 d	0.2 c	0.2 b	–	0.1 b	0.1 c	0.7 b	–
2,4-D	Dicamba on 7/2	0.1 c	1.5 b	0.1 b	97	1.3 a	1.9 b	2.1 a	+13
Chopper	Cultivation on 6/29 and 7/7	3.1 b	5.7 a	3.5 a	38	2.6 a	8.7 a	2.6 a	69
Light disk	Cultivation on 6/29 and 7/7	2.7 b	11.7 a	3.6 a	69	1.1 a	2.6 b	0.8 b	70
Heavy disk	Cultivation on 6/22, 6/29 and 7/7	70.5 a	10.1 a	3.5 a	95	1.5 a	1.0 bc	0.2 b	87

[1] Values within columns followed by the same letter are not significantly different ($P = 0.05$).
[2] Reduction of weed density on July 13 relative to that on June 22 (heavy disk treatment) or June 29 (other treatments) by post-emergence operations on June 22 through July 7.

Table 5. Effect of pre-plant hairy vetch management and post-emergence weed management on populations of annual broadleaf weeds during the 1999 early planted crop.

		Annual broadleaf population (number m^{-2})[1]			
Pre-plant treatment	**Post-emergence operation**	**6/1**	**6/7**	**6/14**	**Percent reduction[2]**
2,4-D + paraquat + atrazine + metolachlor	Dicamba on 6/11	0.4 b	12.5 a	0.5 ab	96
2,4-D	Dicamba on 6/11	0.1 b	3.1 b	0.1 b	97
Heavy disk	Cultivation on 6/3 and 6/11	3.5 a	9.3 ab	0.6 a	94

[1] Values within columns followed by the same letter are not significantly different ($P = 0.05$).
[2] Reduction of weed density on June 14 relative to that on June 7 by post-emergence operations on June 11.

Table 6. Effect of pre-plant hairy vetch management and post-emergence weed management on populations of annual broadleaf weeds during the 1999 late planted crop.

		Annual broadleaf population (number m^{-2})[1]				
Pre-plant treatment	**Post-emergence operation**	**6/14**	**6/24**	**6/29**	**7/6**	**Percent reduction[2]**
2,4-D + paraquat + atrazine + metolachlor	Dicamba on 7/3	0.2 b	0.3 a	12.9 ab	0.4 c	97
2,4-D	Dicamba on 7/3	0.2 b	0.3 a	8.5 bc	0.3 c	96
Chopper	Cultivation on 6/25 and 7/2	0.0 b	1.0 a	4.1 c	1.5 b	65
Light disk	Cultivation on 6/25 and 7/2	0.4 b	1.7 a	9.8 bc	3.9 a	60
Heavy disk	Cultivation on 6/19 and 7/2	2.3 a	0.7 a	25.1 a	2.9 ab	88

[1] Values within columns followed by the same letter are not significantly different ($P = 0.05$).
[2] Reduction of weed density on July 6 relative to that on June 29 by post-emergence operations on July 2 or 3.

however, this was not possible in the untilled soil with high residue levels left by the stalk chopper and light disk.

At the conclusion of post-emergence operations, there were more annual broadleaf weeds in treatments receiving cultivation than in those receiving herbicides (Table 2 and last population assessment date of Tables 3–6). Following cultivation, there were few differences in final broadleaf populations between pre-plant treatments with heavy disk, light disk or chopper. Broadleaf populations following pre-plant and post-emergence herbicide applications were usually less than 0.5 plants m^{-2}, whereas broadleaf populations following pre-plant and post-emergence mechanical operations exceeded the 2.3 plants m^{-2} threshold for corn yield loss in two of the four experiments.

Percentage reduction of weed populations by post-emergence operations, based on populations before and after operations, are shown in Tables 3–6. Annual broadleaf populations were reduced by 96–97% by dicamba, except in the early 1998 experiment, where control was only 88% for annual broadleaf weeds following a pre-plant treatment of 2,4-D alone. In this case, some smooth pigweed plants exceeded the maximal size for control by dicamba. Dicamba would not be expected to control yellow nutsedge; populations of this weed increased in all herbicidal treatments in 1998 (Tables 3 and 4).

Cultivation following the heavy disk reduced annual broadleaf populations by 87–95% (Tables 3–6). Cultivation following the light disk which left minimal residue on the soil surface, in the early 1998 experiment, reduced broadleaf weeds by 82%, comparable with that following the heavy disk treatment (Table 3). Cultivation of untilled soil following the light disk in the late 1998 and 1999 experiments reduced annual broadleaf populations by 60–69%, and cultivation following the stalk chopper reduced broadleaf weeds by 38–65% (Tables 4 and 6). Thus, broadleaf weed reduction by cultivation of soil already loosened by the heavy disk was higher than that when cultivation of untilled soil followed the light disk or stalk chopper. Similar levels of control have been reported by others for cultivation in no-tillage systems. Hanna et al. (2000) reported weed population reductions of 67–79% for cultivation of no-tillage corn. Cultivating no-tillage corn without herbicides provided 62–79% weed control when following a previous corn crop (Buhler et al., 1995). Two cultivations without herbicide provided 63–82% control of broadleaf populations, but one cultivation gave 36–56% broadleaf control for no-tillage corn following a previous alfalfa crop (Buhler et al., 1994).

At the time cultivations began, smooth pigweed sizes ranged from seedlings of 2.5 cm to more established plants of 7.5–15 cm in height. Apart from small and fragile (<5 cm) smooth pigweed plants, the majority of in-row plants survived cultivation (Fig. 1). A rectangular hyperbola model predicted survival of 30, 50 and 92% for pigweed 2.5, 5 and 15 cm high, respectively. In contrast, only 6% of 11 cm high pigweed plants survived when treated with dicamba (data not shown). Since there were many plants more than 5 cm high at the time of post-emergence operations in these experiments, a higher proportion of broadleaf weeds would be expected to be controlled by herbicide than by cultivation.

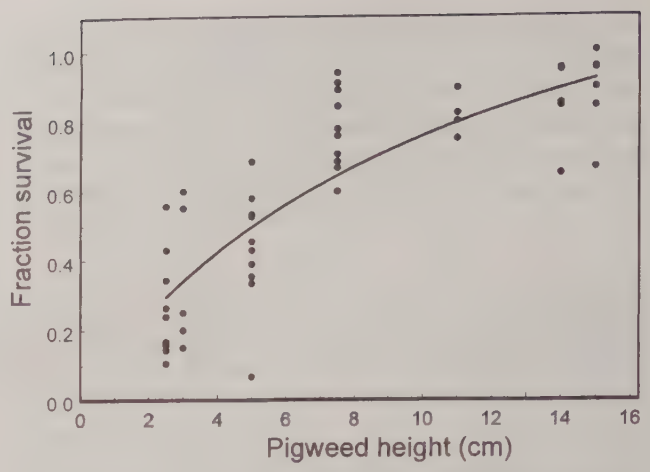

Figure 1. Survival of smooth pigweed within the corn row as a function of smooth pigweed height at the time of cultivation. The regression equation is $y = 0.144x/(1 + 0.0901x)$, where y is the fraction of smooth pigweed surviving and x is the height of smooth pigweed at cultivation ($R^2 = 0.73$).

Discussion

No-tillage crop production typically relies on a mixture of 'knock-down' herbicides, such as paraquat or 2,4-D, for killing existing vegetation, and 'residual' herbicides, such as atrazine and metolachlor, for preventing emergence of weeds later in the season. However, recent research has shown that use of residual herbicides with a hairy vetch cover crop is often ineffective, because the dense layer of residue on the soil surface adsorbs herbicide, thereby decreasing the soil solution concentration (Teasdale et al., 2003). Smooth pigweed and yellow nutsedge should have been controlled by the residual herbicides used in this pre-plant treatment, but were not, in all but the late planted 1998 experiment, probably because of interception of metolachlor by hairy vetch residue and resistance of smooth pigweed to triazine herbicides. The approach of killing hairy vetch with 2,4-D without residual herbicides, followed by a post-emergence herbicide as needed, was as effective as that with residual herbicides for controlling annual broadleaf weeds. However, the presence of perennial weeds, such as yellow nutsedge in 1998, can become a problem associated with the sole reliance on post-emergence herbicides, unless effective herbicides are available for their control. Also, paraquat rather than 2,4-D would have been an option for initial burndown if volunteer grains and/or other winter weeds had been present. Thus, use of a cover crop for suppressing early weed emergence, plus post-emergence herbicides for

controlling later emerging weeds, can eliminate the need for residual herbicides.

These results confirm that killing hairy vetch with mechanical treatments depends on the growth stage of hairy vetch. Pre-plant treatment with various mechanical implements could not both kill hairy vetch and leave high residue levels when hairy vetch was treated in the vegetative stage. Operations by the flail mower, corn stalk chopper or light disk which left high soil residue coverage usually resulted in hairy vetch regrowth. At the vegetative stage, the only effective means of managing hairy vetch without herbicides was incorporation. However, when performed while hairy vetch was flowering, these mechanical implements gave good hairy vetch kill and left high residue levels, comparable to those achieved by the herbicide treatments. Flail mowing required slower speeds of operation than the light disk and stalk chopper, and left the residue shredded, resulting in faster decomposition. The light disk treatment was less consistent, but performed well if set to skim the surface of the hairy vetch vines and to avoid burying residue. The stalk chopper offers good potential for hairy vetch management. More research and development is needed to design equipment with more aggressive cutting action, to kill both vegetative and flowering stands of hairy vetch and other important cover crops (Creamer and Dabney, 2002).

In these experiments, it was possible to control weeds without herbicides in minimum-tillage systems, although not with the same consistency as with herbicides. Keeping hairy vetch residue on the soil surface by pre-plant treatment with a stalk chopper or light disk in the late planted experiments suppressed early weed emergence, compared to incorporation of most residue with a heavy disk. However, weeds of large size, which could not be controlled by the time cultivation began, developed within the rows in all systems. The efficiency of reducing weed populations by cultivation was lower following the stalk chopper (38–65%) or light disk (60–69%) than following the heavy disk (87–95%). It is likely that the initial loosening of soil by the heavy disk led to more efficient uprooting of weed seedlings during the cultivation operations and enabled work to be carried out closer to the row. Thus, although maintaining surface cover-crop residue without tillage initially reduced weed emergence, it also reduced the efficiency of cultivation, leading to similar final weed populations in all mechanical-based, pre-plant treatments. These results suggest a number of areas requiring future research. Current cultivation equipment is designed primarily for operation in tilled soil. New equipment designs are needed to permit efficient cultivation in no-tillage soils. In particular, more effective methods for controlling weeds within the rows are needed for minimum-tillage systems. This could be accomplished either by delaying weed emergence relative to crop development, perhaps by increasing mulch rates within row, or by developing systems that allow more precise control of weeds in the row at an earlier stage. Finally, research is needed to determine whether weed population thresholds for crop yield loss in organic and/or reduced-input systems may be different than in conventional systems. Perhaps more weeds can be sustained without crop yield loss in organic systems because of differences in resource availability. Perhaps more weeds can be sustained without increasing weed seedbanks in organic systems because seed predation and decomposition rates may be higher. Research on any specific weed management strategy for organic systems must be conducted within a more complete understanding of weed population dynamics in these systems in order to develop a comprehensive strategy for long-term weed control.

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The mission of land grant colleges of agriculture

Robert L. Zimdahl

Abstract. *This paper examines what land grant colleges of agriculture were designed to be and do and, using their published mission statements, discusses what they now claim to be and do. Teaching 'such branches of learning as are related to the agriculture and the mechanic arts' and 'to promote the liberal and practical education of the industrial classes' is what land grant colleges were designed to do; it is the land grant mission. The paper asks whether these things are what land grant colleges of agriculture do now. The original mission has been amended with new challenges that must be met in a time of declining public support for higher education, societal distrust of science and a negative public perception of agricultural technology, in a culture that wants cheap food. The agricultural community, including colleges of agriculture, has been slow to accept the challenges and opportunities inherent in the questions agriculture now faces. Agriculture remains an essential human activity in our post-industrial, information-age society. Colleges of agriculture are in trouble, and this paper suggests that the sensible thing to do may be to turn away from self-interest in survival to take a leadership role with emphasis on the obligations of service and humanism.*

Key words: agriculture's mission, land grant university, mission statement, Morrill Act

Introduction

'Agriculture's mission: Finding a partner' was published in this journal (Zimdahl and Speer, 2001). During review it was suggested that the article should also include analysis of the mission statements of land grant university colleges of agriculture. Their role was mentioned but inclusion of their mission statements was beyond the scope of that article. The review comments were appropriate and encouraged thought about the university's role in agriculture and agricultural research. The purpose of this paper is to analyze the mission statements of a representative group of US colleges of agriculture and to continue the discussion of the mission of agricultural science begun in the previous paper (Zimdahl and Speer, 2001).

Logsdon, a farmer and writer, wrote a scathing critique of colleges of agriculture (Logsdon, 1994) that addressed the failure of agricultural education. In his view, agricultural education had failed because it missed the organic agriculture movement, served the wrong audience, and stood by quietly while government policies destroyed moderate-sized farms. As these things occurred, the number of agricultural faculty increased but the faculty abandoned moral and philosophical leadership of agriculture and rural society (Logsdon, 1994). Logsdon claimed that professors were overpaid, had enviable retirement and benefit programs, pursued money rather than truth, and really didn't need tenure because they rarely said anything controversial.

There is no question that the task of all colleges of agriculture has become more challenging in recent years, primarily because societal expectations of agriculture and of universities have changed. Those who administer and work in colleges of agriculture observed the changes, but may not have realized all the implications until the changes were upon them. Agriculture still has its important original mission: to produce an abundant supply of food and fiber reliably and cheaply. However, over what seems like only a few years, that mission was amended, with new challenges that demand that colleges of agriculture:

- reduce consumption of finite resources (e.g., fossil fuel and water);
- avoid or minimize environmental damage;
- minimize or eliminate toxic residues in the environment and in food;
- reverse deterioration of rural communities; and
- preserve long-term productive capacity, i.e., become sustainable.

These challenges are recognized in the mission statement of the College of Agricultural and Life Sciences at North Carolina State University, which noted changes that are transforming American society and have created paradoxes of change that affect the land grant mission. These include: declining support for higher education, societal distrust of science and intellect, a public perception of agriculture and its tools—chemicals, biotechnology and other technical advances—that is becoming more negative, and a culture that relies on cheap energy and abundant food while demanding a cleaner environment.

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The things mentioned above are large changes and major challenges for any enterprise, and they are especially burdensome when one doesn't see them coming, ignores them, is not sure how to solve the problems they create, and has no new resources and the same staff to address the new challenges. To illustrate, higher education's share of state spending across the US fell by 14% from 1986 to 1996, while Medicaid's share doubled and the share of funds to prisons increased by 25% (Yudof, 2002).

Agricultural practitioners, administrators of colleges of agriculture and faculty members were not educated to question practices or results, and have not given much time to self-scrutiny. University agricultural faculty members were, as they understood it, engaged in any country's most important activities—food and fiber production and education of the young. These activities were viewed as unquestionably good, and all involved in agriculture believed they were of undeniable, even ultimate, importance. Those who criticize agriculture's emphasis on short-term economic and technical efficiency have often been from outside agriculture and almost always from outside colleges of agriculture. The system, and those in it, have typically responded, if the critique was even acknowledged, with hostility and defense. The defense argued that agriculture was one of the few essential human activities, and that the critics had no credentials or expertise in agriculture and clearly did not understand farming.

In Logsdon's (1994) view, when colleges of agriculture began to serve the audience that viewed agriculture primarily as a business, rather than serving those who saw agriculture, at least partially, as a way of life that was inherently important, the colleges became willing contributors to research and policies that have led to several bad things:

1. Food and fiber production have been maintained and increased with a concomitant worsening of the long-term health and supply of the nation's soils and groundwater.
2. Plant and animal genetic diversity have been reduced.
3. The US diet favors animal products over plant products.
4. There is reduced flexibility of agriculture's political and economic system that has reduced crop and livestock choice among farmers.
5. The agricultural system is capital, energy and chemically intensive, with a requirement for high production volume and low cost.
6. There has been a steady decline in the number of small and medium-sized family farms. The 2000 US census data reinforce this claim. Forty-seven of North Dakota's counties, 53 of 93 Nebraska counties, more than one-half of Kansas' counties and 45 of Iowa's 95 counties lost residents from 1990 to 2000 (US Census, 2000). Twenty-five Minnesota counties lost residents, almost all along the state's agricultural western and southern boundaries (US Census, 2000).

It would seem clear that Comstock's (2000) claim that 'The land-grant university system has not taken care to make sure its research is equally beneficial for all size farms' is true. Berry (2000) claims that these changes began with the introduction of the internal combustion engine tractor. He says:

> They replaced agriculture's old dependence on the free energy of the sun with a dependence on purchased energy; in general they increased farming's dependence on a supply economy that farmers cannot control or influence; over the years, these dependences have radically oversimplified the patterns of farming, replacing diversity with monoculture, crop rotation with continuous tillage, and human labor with machines and chemicals; they have replaced (in Wes Jackson's words) nature's wisdom with human cleverness; they have caused widespread, profound social and cultural disruption. All these changes are still in progress. Whatever the technological or quantitative gains, this industrialization of farming has been costly, and it will continue to be. Most of the costs have been 'externalized'—that is, charged to nature or the public or the future.

Berry (2000) then says 'The response to this in the land grant universities has been applause.'

Many agricultural faculty will claim that their research and teaching didn't cause these things. They may be correct. Logsdon's (1994) and Berry's (2000) claims, while debatable, are generally true, and denial of the charges risks the accusation that whatever agricultural faculty were doing was totally irrelevant to the creation of the modern agricultural system that these things describe accurately.

These are harsh claims and agriculturists ought to ask if they are true. To begin to answer the question, this paper will examine what land grant colleges of agriculture, as part of the land grant college system, were designed to be and do, and, using the college's published mission statements, what they now claim to be and do. The balance of the paper will examine these two things, albeit the latter in more detail than the former.

What is a Land Grant University College of Agriculture?

As far as can be determined, all colleges of agriculture in land grant universities are federal, state and local government partnerships that are dedicated to agricultural education, research and extension.

Representative Justin Morrill of Vermont introduced the first land grant university bill in 1857; it did not become law. After lengthy, often acrimonious, debate, especially from southern states (Busch and Lacy, 1983), about its constitutionality and effects on US Treasury revenue, a successful bill was introduced on December 16, 1861. It narrowly passed the House (105 to 100) but easily passed the Senate (32 to 7). The Morrill Act said its 'leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such

branches of learning as are related to agriculture and the mechanic arts'. This was to be done 'to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life'. The successful legislation granted each state 30,000 acres (12,150 ha) of land for each US Senator and Representative in the state, based on the 1860 census. The first Morrill Act was signed into law by President Abraham Lincoln on July 2, 1862. The proceeds from the sale of the land in each state were to be invested in a perpetual endowment to support 'the agriculture and mechanic arts' in each state. Thus, the name land grant colleges. The second Morrill Act was signed by President Benjamin Harrison on August 30, 1890. It extended the land grant benefit to 16 southern states and to some historically black, southern colleges. These two acts established the educational base for land grant colleges. Native American colleges were added in 1994.

The Morrill Acts were complemented by the Hatch Act of 1887, which provided funds to establish an agricultural experiment station affiliated with each college of agriculture in each state. The third part of the modern land grant system was created by the Smith–Lever Act of 1914, which established the Cooperative Extension Service as a joint venture between the US Department of Agriculture and the previously established land grant universities. The act required that federal funds be matched by local funds, and that endures to this day.

The mission of the Morrill Act within colleges of agriculture has been viewed as promotion of a sound and prosperous agriculture and rural life, because these were viewed as indispensable to national prosperity and security. This was to be done through teaching. Until the late 19th century, US colleges and universities were primarily teaching institutions, and their role was transmission of knowledge (Lawry and Anderson, 2000). Research was not part of the original mission but was quickly added, although what was to be studied was not clear (Busch and Lacy, 1983). Promoting a sound and prosperous agriculture and rural life is what many view as the primary mission of land grant colleges of agriculture; it has come to be viewed as part of the land grant mission. Is it what they do now? Have their professed objectives regularly worked toward this goal, or have they diverged? To discuss these questions this paper will now examine the publicly available mission statements of one representative land grant college of agriculture (or the equivalent name) in each of the 50 US states.

Mission Statements of US Colleges of Agriculture

This first survey was completed in the summer of 2000. The internet site for the selected land grant university in each US state was examined to find the college of agriculture portion and that was examined to find the mission statement. The survey was repeated in the spring of 2002. An intentional limitation of each survey is that it included only one land grant university from each state. This limitation excluded some institutions that include agriculture (e.g., California Polytechnic). Among the first things learned from the 50 mission statements is that not all the colleges that, in earlier days, were probably colleges of agriculture (their developmental history was not examined) are now known by that name. Of the 50 land grant universities surveyed, 13 have Colleges of Agriculture and four have Colleges of Agricultural Sciences (Table 1). Ten are called the College of Agriculture and Life Sciences. Of those, New Hampshire reversed the names and Clemson (SC) has a College of Agriculture, Forestry and Life Sciences. Ten use College of Agriculture and Natural Resources. Missouri places food between agriculture and natural resources, and Nevada, alone among the 50 surveyed, lists biotechnology (as the second name). Five universities have a College of Agricultural and

Table 1. The name of the college that deals with agriculture in 50 US land grant universities.[1]

College name	Two-letter US State name
College of Agriculture	AL, AR (Division of Agriculture), AZ, IN (School of Agriculture), IA, ID, KS, KY, LA, MT, ND, UT, WY
College of Agricultural Sciences	CO, NJ, OR, PA
College of Agricultural and Life Sciences	FL, MS, NC, NH, NY, SC, TX, VA, VT, WI
College of Agriculture and Natural Resources	CT, DE, HI (Tropical Agriculture), MD, MI, MO (food is listed second), NE, NV (biotechnology is listed second), OK, TN
College of Agriculture and Environmental Sciences	CA, GA, IL (consumer sciences are second), MN (food is second), OH (food is first)
School of Agriculture and Land Resources Management	AK
College of Agriculture, Forestry and Consumer Sciences	WV
College of Natural Science, Forestry and Agriculture	ME
College of Agriculture and Home Economics	NM, WA
College of Agriculture and Biological Sciences	SD

[1] The total is 48 because the land grant universities in Massachusetts (College of Food and Natural Resources) and Rhode Island (College of Environment and Life Sciences) do not include 'agriculture' in the name of the college.

Environmental Sciences, although there is little consistency in the name order. Two (GA and CA-Davis) use the above title. Illinois places consumer sciences between agriculture and environmental sciences, Minnesota places food second, and Ohio places food first. The remaining eight use several different names. For example, agriculture is not included in the name of the University of Massachusetts College of Food and Natural Resources or in the name of Rhode Island's College of Environmental and Life Sciences. The names of the land grant universities surveyed are shown in Table 1.

Each institution attaches special significance to the name chosen for its college. The name reflects the disciplinary departments in the college and the chosen program emphasis. Merging of colleges and functions occurs to provide proper program emphasis, save money, and streamline operations. It is not the purpose of this paper to judge any institution's name choice. The names represent the disciplinary diversity in each college and the college's program emphasis. The diversity of names is interesting, but exploration of names is not the purpose of this paper.

Mission statement goals

As expected, the range of goals mentioned in mission statements is quite large. No two colleges express their mission in the same words. Each college is bound by the mission of the university it is a part of, and by its geographic place, its tradition, its constituency, budget realities, the skills and desired goals of its administration and faculty, the direction provided by external constituencies (e.g., the legislature and funding agencies) and the historical period.

The internal goals in the mission statements of several colleges are important. These include achieving excellence (excellence is used by 19 colleges), acquiring more undergraduate and graduate students, increasing use of technology, acquiring more external grant/contract support, demonstrating more scholarly productivity, building more and better laboratories, establishing multi-state and multi-disciplinary collaboration, and raising more money. These instrumental goals lead to greater ability to accomplish the college's mission. They are not presented in mission statements and are not regarded herein as statements of the college's mission. A, usually unstated, part of any college's mission is to endure, and the things mentioned above are essential to endurance. These instrumental goals are not, except as resources are required, central to the tripartite mission of teaching, research and outreach (often called extension) of land grant university colleges that include agriculture. Five colleges (Arizona, Indiana, Nebraska, Ohio and Texas) state that part of their mission is to become the premier agricultural college in the US. It is not an objective of this paper to judge their success.

The previous analysis (Zimdahl and Speer, 2001) of institutional missions was easier. It is trite to say that colleges of agriculture are complex. It wrong to say that because they all may strive to do the things embodied in the land grant mission–teaching, research and outreach, it is unlikely that they will all conceive their mission in the same way. Alabama is not Alaska, Maine is not Montana. The extant agriculture, the geologic, social and political environments, and the people to be educated and served differ. Their missions cannot be the same, although most are similar.

Many words and phrases are used to express the mission of the 49 (all except Rhode Island) colleges in land grant universities surveyed for this report, each of which has a name that includes agriculture or food (Table 1). What differs is the words each uses to express the mission. The variety of words used in the mission statements can be summarized by the three words that best describe the traditional land grant mission—education, research, and service or outreach. All surveyed colleges claim an educational role as part of their mission (Table 2). The diverse expressions of the essential mission can be further divided within service and research (Table 2). Service can be divided into a local, societal and an international mission. Research was divided into three categories: environmental, economic and agricultural (Table 2). The key words used in Table 2 are those that appeared most frequently in the mission statements. They were identified as the mission statements were read, rather than being selected in advance.

One should not expect different groups of academics to use identical words to express similar missions. However, in view of the shared land grant tradition, and in spite of their diverse geologic, social and political environments, it is not unreasonable to expect them to create mission statements that express the tradition they share. As Table 2 shows, all include education. All, although the emphasis varies, include some aspect of local service, with words such as serving the needs of the state's people, producing safe, nutritious food (also an agricultural goal), caring for local communities, quality of life, families and producing good citizens. Larger social goals, such as producing productive citizens, developing leaders and assisting students to reach their full potential, are mentioned by only 27 colleges. Inclusion of an international audience is mentioned by only 23, although, one expects, all are pleased to enroll foreign students. Cultural and ethnic diversity are mentioned by only 11 colleges.

Only two of 49 colleges do not mention the environment or natural resources. Twenty-two do not mention economic goals for agriculture, such as economic security, economic viability, and economic growth and development. It is interesting that 42 mention one of the specific agricultural goals, such as to enhance or improve agriculture (19), to make agriculture more profitable and competitive (14), to sustain agriculture (15), to transfer agricultural technology (6) or to provide research-based information (24). Only Nevada gives biotechnology major emphasis in its name, although four other colleges mention its importance. One

must assume all have developed, or are developing, biotechnology classes and research programs.

The mission statement of Purdue University's School of Agriculture (Indiana) is brief, but adequately summarizes what many other colleges mission statements say. It says that their mission is to:

1. Develop the best human resource base that we can possibly achieve through educational programs; and
2. Create new knowledge and apply it to the solution of relevant problems in the food and natural resource systems.

Analysis of mission statements

Land grant universities, and their colleges that deal with agriculture, face huge challenges, as does all of modern agriculture. Our college leaders owe it to their institutions, the faculty and the students to address Logsdon's (1994) harsh claims. The mission statements begin to address the complex issues, but fall short of the task. The complexity of a college's task is evident in the seven challenging dilemmas, outlined by Evans (1998), that each college and each agricultural scientist ought to consider:

1. The Malthusian dilemma. Has the largely successful quest to increase food production simply enlarged the human population and thus depleted non-renewable resources and harmed our ecosystem?

2. The demographic transition dilemma. If development is the best contraceptive, and if agriculture's technical advances create development, then to be effective for development those advances have to be quickly and widely adopted, as many were during the green revolution. Where technology or innovations [e.g., high-lysine corn (Evans, 1998)] are not quickly and widely adopted, their affect on development is equivocal.

3. The environmental adversity dilemma. Agricultural research has been carried out overwhelmingly in environments where the hope for success is high. Research in unfavorable environments, which have poor infrastructure, degraded soil, and few or no available technical inputs, has less hope of rapid success and has been largely ignored by US colleges of agriculture. A different environmental claim also comes from those who think modern agriculture is environmentally harmful. The specifics of the charge need not be debated here, but for those in agriculture the issue is not whether the environment will be altered, but to what degree and how extensive the damage is (Aiken, 1984), and what kind of agriculture can be sustained over time without irreparable environmental harm. Agriculture's defenders argue that we must have food to survive. Human needs are primary and the environment must be managed to produce food (Aiken, 1984). Aiken (1984) asks, 'If human needs are not primary, then what is?' What is a reasonable alternative to increasing production to feed a growing population? Letting people starve is obviously a moral wrong.

4. The scale-positive dilemma. Most agricultural innovations are scale-positive, in that the benefits are more readily available to large-scale farmers who have access to credit, information and resources. Agricultural technology developed or recommended by agricultural colleges, and that which has been created elsewhere (e.g., pesticides, new machinery), can magnify injustice if small-scale farmers are driven out of agriculture.

5. The sustainability dilemma. How does agricultural science balance the quest for more production with the necessity to maintain the environment on which production depends? The dilemma is shown by the metaphors used in agricultural language. Agriculture has been seen by farmers and scientists as an essential battle with nature. To succeed, those who practice agriculture have to compete, rather than cooperate, with nature. Agriculture, one of the most important of all human activities, must find ways of extracting from the ecosystem enough resources to maintain human life. But being part of the web of life, dependent on nature, has been foreign to agriculture. Nature, in agriculture's metaphorical language, must be managed, beaten back at every turn. The natural world is not the Garden of Eden but a fallen world (Belsie, 2000; White, 1967). Agricultural scientists 'see themselves as helping to feed and clothe the rapidly growing human population while cherishing the earth' (Evans, 1998). Agricultural practitioners tend to believe that 'Whoever farms land will be rewarded by God every time a person eats from its crop, even if a thief steals and eats from it' (Hathout, 1995). Part of the challenge to this belief and the quest for sustainability is the fact that others see agricultural scientists and colleges that teach modern agriculture as 'destroyers of nature, wastrels of water, eroders of land and genetic resources, polluters of the environment, and hand-maidens of agribusiness' (Evans, 1998).

6. The advancing or maintaining dilemma. 'Exploratory research leading to new agronomic procedures, better adaptation or higher yield potential is one key to feeding the world' (Evans, 1998). It is equally important to learn how to apply what we already know. This maintenance research is not what lures young scientists. It is not the cutting edge where progress is made and careers are formed. It seems dull and is avoided.

Lockeretz (1995) advocated removing applied (maintenance) agricultural research from the academic world. It could then be treated as what it is—a worthy but non-academic activity that is a service to the university's outside constituencies. Lockeretz (1995) suggested there is a mismatch between the worthy 'goals of much agricultural research and the ethos of traditional academic scholarship'. Thus, the root of what Evans (1998) sees as the advancing or maintaining dilemma and Lockeretz identifies as a fundamental conflict of goals, is the question of for whom the research is done. The audience for traditional academic research is usually one's scientific peers. They are the users. The audience for much agricultural research is partially one's scientific peers, but it is also the farmers and ranchers and agribusiness companies who will adopt or adapt and use what is learned. It is believed that agricultural

Table 2. Key words from mission statements of agricultural colleges in 49 US land grant universities.

Key words	State																									
	AK	AL	AR	AZ	CA	CO	CT	DE	FL	GA	HI	IA	ID	IL	IN	KS	KY	LA	MA	MD	ME	MI	MN	MO	MS	MT
Education																										
learning/education	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
develop students	x	x		x	x	x			x		x		x		x	x				x						
land grant mission	x			x		x	x		x		x						x	x	x	x	x	x	x	x		x
leadership		x	x			x			x						x					x		x				
professional career/future						x						x											x			
Service, local																										
serve needs of people	x	x	x	x	x	x	x		x	x		x	x		x	x	x	x	x	x	x	x		x	x	x
safe, nutritious, affordable food			x		x	x			x	x			x	x	x	x	x			x			x		x	
local communities			x	x	x	x	x		x		x	x	x			x	x					x	x			
quality of life			x	x		x	x	x	x				x	x		x				x		x				x
families			x	x			x			x			x					x		x						
good citizens		x	x		x	x				x			x							x						
Service, societal																										
social goals		x	x	x		x			x		x	x	x			x	x	x	x			x		x	x	
diversity			–			x	x		x						x							x				
Service, international																										
international		x		x		x		x	x	x	x	x	x				x	x				x		x	x	
Research																										
environment		x	x	x	x	x	x	x	x	x	x	x	x		x			x	x	x		x	x	x	x	x
natural resources	x	x	x	x	x	x	x	x	x	x			x	x	x	x		x		x	x	x		x	x	x
stewardship			x			x				x					x	x								x		
economic security			x								x	x										x			x	x
economic viability										x	x		x											x		x
economic growth and development							x						x			x			x				x	x		
enhance/improve agriculture			x	x	–	x	x	x		x					x	x				x		x	x	x		x
agriculture profit and competitiveness						x							x	x			x									x
sustain agriculture	x					x			x							x	x			x				x		
technology transfer		x									x	x							x							
science/research based information		x	x	x		x	x	x	x	x	x				x					x				x		x
biotechnology							x	x	x																	
to be the premier college				x											x											

Table 2, *Continued*

Key words	State																							Total
	NC	ND	NE	NH	NJ	NM	NV	NY	OH	OK	OR	PA	SC	SD	TN	TX	UT	VA	VT	WA	WI	WV	WY	
Education																								
learning/education	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	46
develop students	x									x	x													14
land grant mission	x	x	x		x	x		x		x	x		x	x		x	x	x		x			x	30
leadership	x					x				x					x			x				x		13
professional career/future	x				x		x						x											7
Service, local																								
serve needs of people	x	x	x		x	x		x	x		x	x	x			x	x		x	x		x	x	38
safe, nutritious, affordable food				x	x	x	x	x			x				x				x	x				22
local communities						x		x	x	x	x					x	x		x	x	x		x	24
quality of life	x			x				x		x				x	x		x		x		x	x		22
families							x								x					x			x	11
good citizens																	x	x						10
Service, societal																								
social goals	x		x		x	x		x	x	x		x				x	x	x			x			27
diversity									x			x			x		x		x		x			11
Service, international																								
international	x							x	x		x	x				x		x	x			x		23
Research																								
environment	x		x	x	x	x	x	x		x	x	x	x		x	x	x	x	x		x	x		39
natural resources			x	x	x	x	x	x	x	x	x	x	x	x	x	x		x		x	x		x	39
stewardship									x		x	x				x				x	x			12
economic security	x				x		x			x		x		x	x	x								14
economic viability			x				x				x					x	x			x	x			12
economic growth and development				x	x										x									9
enhance/improve agriculture	x									x	x	x	x		x									19
agriculture profit and competitiveness				x	x	x				x	x		x		x				x				x	14
sustain agriculture				x		x		x		x	x							x		x			x	15
technology transfer			x			x																		6
science/research based information						x		x	x		x		x	x			x			x	x	x	x	24
biotechnology					x		x																	5
to be the premier college			x						x							x								6

research ought to be useful to agriculture—to farmers and ranchers. Research that is immediately useful is not bad science, but as Lockeretz (1995) points out, 'if research is to be more a service and less an academic activity, this would require parts of agricultural science to forgo some of the status they gained when they became less practice-oriented and more academic'. Agricultural scientists 'gained the prestige associated with the academy at a cost: the possible conflict between serving the world of scholarship and serving the world of agriculture' (Lockeretz, 1995). Serving the world of agriculture is often not cutting-edge science where careers are made. The choice—cutting edge and scientific progress versus service and possible dullness—is fundamentally a choice of audiences. If the scientific community of peers is the audience, then the route is obvious. The agricultural community, the historically established audience of the land grant college of agriculture, seems to be the right choice, but it is not the obvious choice in mission statements. Berry (2000) argues the same point in the context of professionalism that, in his view, 'aspires to big answers that make headlines, money and promotions'. Local answers are small answers, but these are not pursued by professionals (Berry, 2000).

7. The optimist/pessimist dilemma. As they view the future, agricultural scientists must decide to act in accordance with the pessimistic views expressed by Lester Brown of the Worldwatch Institute and Paul Ehrlich of Stanford University, or the optimistic views of Dennis Avery of the Hudson Institute and Julian Simon (University of Maryland, deceased). Few want to be Luddites and appear to be against all that is new. Pessimism may lead to nihilism and inaction. Optimism can mobilize hope and action, but may also lead to complacency.

The Challenge and the Mission

'The land grant university system was one of the great institutional innovations of the 19th century' (Schuh, 1986). To attempt to educate all comers in agriculture and the mechanic arts was a new adventure. To do so by creating the tripartite mission that went beyond education to research and service was revolutionary. Schuh proposed in 1986, what Logsdon claimed in 1994, that 'the land grant universities have lost their way' because they gradually abandoned their traditional audience. In view of the complexity of the task outlined by Evans (1998), it is not surprising that the way has been difficult.

The mission of land grant colleges of agriculture is still unclear within and outside the institutions. The initial focus (prior to the Second World War), expressed by Kunkel and Thompson (1996), was to train students 'who were either coming from or heading to rural communities, and who had food and fiber production in mind as their primary reason for being there'. In the late 19th century there was disagreement about the value and appropriateness of laboratory or field and science versus system research (Marcus, 1985). Farmers generally thought colleges of agriculture should teach students how to farm successfully, and distrusted science. Most people agreed with Will Rogers that an education 'was a fine thing, and every college graduate ought to have one'. But many farmers were suspicious of the utility of a liberal education for agriculture students. The farming community was also not sure of the need for conducting experiments and teaching science (Marcus, 1985). In response, agricultural faculties dropped many of the requirements of a classical education but defended the role of science as a solution to agricultural problems (Marcus, 1985). The focus became, and generally remains, the industrial model of agriculture that is now oriented toward a global, high-technology future (Francis, 2000). Land grant colleges of agriculture seem to focus narrowly on training people for jobs in agriculture where particular skills and knowledge tend to have 'a high rate of obsolescence' (Schuh, 1986). However, mission statements neither emphasize job training and mission, nor do they clearly reflect the fact that agriculture is a 'multi-perspective system that provides food and other products, as well as employment services, and a vital human connection to the natural environment' (Francis, 2000).

The belief in the intrinsic value and goodness of production is so ingrained in the minds of those who write mission statements that it hardly appears in mission statements (Table 2). It appears to be assumed that production is what agriculture is about and its importance or value do not need to be emphasized, or even mentioned. Only 22 colleges mention producing safe/nutritious food, 19 mention enhancing and improving agriculture, and 14 mention improving agricultural profit and competitiveness (Table 2). The total number using these key words is 34 (Table 2) because some mention more than one of the key word groups.

The environment and natural resources are mentioned by 39 colleges, and both terms are used by 31. Stewardship is mentioned by only 12 colleges. No colleges claim that part of their mission is to seek cooperation with environmental or any other groups. Francis (2000) suggests that environmental groups may be among the best potential allies and sources of support. In his view (Francis, 2000) they are logical cooperators because of shared concerns for the environment and the future. Zimdahl and Speer (2001) made the same claim relative to finding partners for agriculture. One must ask if the environment is mentioned because it is important or because it is politically correct? Mission statements do not reveal whether things are mentioned because they are politically correct, or out of real concern, with the intent of shifting institutional orientation away from primary emphasis on production and agricultural profitability.

Agricultural college mission statements may be simply instrumental statements that accomplish the dual mission of assuring parents that their children will get a job when they graduate and providing conformity with the public's desire that universities and their colleges ought to be engaged in

the world. The ultimate test of their engagement may also be a dual test based on the success students have in obtaining jobs, and how readily the knowledge generated through research can be put to use.

Universities and agricultural colleges, one assumes, recognize and will deal with the changing economic realities of higher education in their mission statements (Press and Washburn, 2000; Yudof, 2002). Economic goals are included in what I have called internal goals (see above). The essence of the economic reality is that State government control endures but the State's financial support has declined (Yudof, 2002). If a university is going to continue to perform research, external funding must be obtained. The areas of higher education (not just in agriculture) 'that have succeeded the most in the past 30 years follow at least one of three criteria'. First, there is a promise to the student of higher than average lifetime earnings. Yudof (2002) notes that a male college graduate makes an average of US$32,000 more each year than a high school graduate, and about US$1 million more over a lifetime. The second area of success is the study of money. The third is an area that receives money from outside grants (Mariantes, 2000). These standards of success affect students and faculty. Students enroll in the majors that promise the greatest financial rewards. Agriculture is not one of those majors. Agricultural students and faculty (with the exception of agricultural economists) do not study money. But agriculture faculty and colleges do receive money from outside grants. That money has become the ticket to success for professors and institutions (Press and Washburn, 2000). The mantra of the academy used to be publish or perish. Publication of research is still expected, but obtaining external funding of research is now not just expected but is required of faculty, and is the means to achieve the expectation of publication. External grant funds enable a faculty member to obtain graduate and post-doctoral students and equip labs to do the research that leads to publications. The funds lead to success in the academy. Professors with good grant-swinging ability do not teach much or, perhaps, not at all, because they are too busy with research and the never ending quest for funds to keep programs going. The requirement for funds has led to increased emphasis on a business model that demands competition in the hunt for endowments, research funds and students. Where large size is success and large organizations dominate, there is little room left for the 'craftsman or the scholar' (Carey, 2000).

Thus, we now have an academic–industrial complex (Press and Washburn, 2000). Pollack (2001) suggests that agricultural research is increasingly being controlled by private companies not by land grant universities. Press and Washburn (2000) note that what is most surprising about the academic–industrial complex is not that large amounts of private capital flow into universities, but that universities are beginning to look and behave like for-profit companies. Economic efficiency is the goal. The Vice-President for Research at my university distributed a memo in March 2000 that made things quite clear (Memo of March 8, 2000 to Academic Deans, Associate Deans, and Department Heads from Colorado State University's Vice-President for Research and Information Technology).

> The University must hire future faculty very carefully to continue its success in competing for external resources to support research, scholarship, graduate students and outreach activities. It is prudent that we identify future externally funded research thrusts that are compatible with and support current University strengths, enhance our competitiveness for external funding, are congruent with state and national priorities, and are directed toward building strengths within the university.

A corporate executive could have written the statement. It supports the claim of Press and Washburn (2000) that 'commercial acumen is becoming an important qualification for new faculty'. Universities were once wary of corporate funding, but have become 'eager co-capitalists, embracing market values as never before' (Press and Washburn, 2000). An obvious risk is that the external funds that are necessary for research will determine the university's mission (Press and Washburn, 2000). This view ignores the claim made by Carey (2000) that

> The responsibility of the university is to stand in opposition to whatever *at the moment* is the dominant force and fashion and to align itself with the public and a public interest that is oriented to the conditions of long-run stability.

The public may begin to see professors 'less as stewards of the truth than as hired hands' (Press and Washburn, 2000), or even as interested participants in the commercial enterprise. Agricultural faculties have been, as the system compels them to be, willing participants in acquisition of external funding. Not too long ago the kinds of alliances Press and Washburn (2000) wrote about would have been unthinkable. Now alliances between institutions of a totally different character, such as a profit-making company and a university department, are common (Anonymous, 2001) and desired by both kinds of institutions.

It is an old and compelling argument that the university should not be just the mythical ivory tower. It must be engaged in its community and the world. Creation of knowledge (research) and dissemination of knowledge (teaching) ought to be useful. The conflict is particularly apparent in agriculture (see item 6, above). Table 2 illustrates recognition of the reality of usefulness, as nearly all agricultural colleges strive to educate (46 colleges) and some also want to develop students (14) for leadership roles (13). Press and Washburn (2000) note the intent to produce people 'who are employable in today's technology work force'. The mission, apparently accepted by colleges of agriculture, is not to educate well-rounded citizens but to train people for the work force, in spite of the fact, mentioned above, that training people for jobs in agriculture, or anywhere else, where particular skills and

knowledge are required, tends to lead to 'a high rate of obsolescence' (Schuh, 1986). Education in agriculture is regarded as an instrumental good because it leads to employment. Appropriately remunerative employment and the university experience that leads to it, are now regarded as a private, rather than a public good (Yudof, 2002). Education is not an end in itself, employment is the appropriate and desired end. It is not possible to determine from mission statements whether education is regarded as inherently good but, if it is, it is not apparent.

Courses that do not attract a sufficient number of students are dropped 'while administrators lavish attention on flashy facilities that will attract students' (Mariantes, 2000). College is becoming less about learning and more about money (Mariantes, 2000). Agricultural education risks becoming a service industry, not for farmers and ranchers but for corporate interests. It is also a service for students (the customers, a word used in only a few mission statements), who arrive, look at what is available, and select what appears to be most useful or interesting. Apparently, agricultural education is not inherently good, it has to be useful, or at least momentarily interesting.

Agricultural education has consistently advocated maximizing productivity and profit and supported the policy of minimizing food prices. Agricultural colleges have sought and received praise for keeping (through technology development) US food prices among the lowest (as a percent of disposable income) in the world. Efficient production has led to a steady reduction in the number of farmers. Increased production with fewer farmers has been regarded as success by American agriculture and the land grant colleges of agriculture. It is success that any industrial enterprise would be proud of—more production with fewer people. The dominant agricultural ethos conveniently ignores the fact that the reduced number of farmers often carried the price of individual bankruptcy (Suppe, 1987) and the heartbreak that went with it. The ideal was that as science and technology advanced to make agriculture more efficient, the people who were no longer needed on the farm would find work in urban industrial centers. Agriculture was a source of hard-working people who would build more of the technology that drove them from the farm. The industrial and agricultural revolutions of the 19th century were complementary, but that no longer seems true in the information era.

Busch and Lacy (1983) note that agricultural scientists 'failed to comprehend that science itself is a social process'. Their belief in the claim that science is value-free and autonomous 'had the effect of making science the pawn of vested interests because it served to divert scientific attention away from the question of ends'. Increased production was an unquestioned good goal for agricultural research. If, as production rose, profit also rose, that was always good. If society was still unjust, that was unfortunate but it was not an agricultural problem. Justice is not a bad thing within agriculture, but it is not an agricultural goal. Achieving a just society is not part of the agricultural mission and is not mentioned in any mission statement.

Mission statements do not mention protection of, or serving, family farms. The land grant mission is mentioned by 30 colleges. Serving local communities is mentioned by only 24 and improving or enhancing quality of life by 22 (Table 2). Economic matters such as security, viability, and economic growth and development of the agricultural sector are each mentioned by fewer than 14 colleges. Surprisingly, such things as enhancing or improving agriculture, improving agricultural profit and competitiveness and sustaining agriculture are mentioned as part of the mission by only 65% of the colleges, and all three are mentioned by only three colleges. One begins to wonder who the colleges serve if it is not agriculture and local communities. Perhaps Press and Washburn (2000) are right when they say the agricultural–industrial complex is the audience because of the funding and inevitable intellectual influence it contributes to the colleges. The fact that family farms are disappearing is unfortunate, but their disappearance is regarded as being due to their inability to compete in the modern world. The small family farm does not deserve to survive any more than the corner gas station or the Mom and Pop grocery store (see Hanson, 1996 for a vigorous denial of this view). Its demise illustrates the scale-positive dilemma mentioned by Evans (1998). The goal of the Morrill Act, and thus of the land grant college of agriculture, 'to promote a sound and prosperous agriculture *and* [emphasis added] rural life' (Busch and Lacy, 1983) has not been achieved, but that, in the colleges' collective view, appears to have nothing to do with their mission and program. The mission of the land grant college is not to maintain the status quo and protect what are regarded as inefficient producers, but to survive.

If productive and economic efficiency and survival are the goals, one must ask if the colleges have succeeded. In 1887, the US Congress reluctantly passed the Hatch Act, which gave each State US$15,000 a year to study agricultural problems (Budiansky, 1984). This system has evolved to formula funding for land grant colleges of agriculture. Research supported by these funds tends to focus on short-term, site-specific problems (Budiansky, 1984). Such funding has been nearly non-competitive and has led to a great deal of pedestrian research in land grant colleges of agriculture that would never have been done if the scientists had to compete for funds and endure peer judgment of scientific merit (Budiansky, 1984). The work has focused on practical problems important to a small number of farmers and has neglected basic research on which scientific progress is dependent (Budiansky, 1984). It has not been bad science. It has been narrowly focused, applied research. For example, in weed science many studies have been done to test the unstated hypothesis that weeds reduce crop yield. The studies ask and determine what happens; most do not attempt to ask why.

The goals of increased production and economic efficiency have been achieved in the US and other

developed countries. The Economist (Anonymous, 2001) notes:

> Every single European country now has large and increasingly unsaleable farm surpluses. In quantitative terms, farm production in most developed countries today is probably at least four times what it was in 1920 and at least three times what it was in 1950 (except in Japan). But whereas at the beginning of the 20th century farmers made up the largest single group in the working population in most developed countries, now they account for no more than 3% in any developed country. And whereas at the beginning of the 20th century agriculture was the largest single contributor to national income in most developed countries, in 2000 in America it contributed less than 2% to GDP.

As their numbers declined, farmers have become a 'unified special-interest group that carries disproportionate clout in all rich countries' (Anonymous, 2001). For every 1% that agricultural prices and employment have fallen in the 20th century, agricultural subsidies and protection, and thus economic success in American agriculture (and all other developed countries), has increased by 1% or more (Anonymous, 2001). No matter how agricultural colleges describe their mission, their work has affirmed Schumpeter's (1950) postulate that dynamic disequilibrium and creative destruction are the driving forces in any modern economy.

The undeniable success of the American colleges of agriculture in our land grant universities in increasing agricultural production and making agriculture more labor, and thus economically, efficient are often the envy of the world agricultural community. Production and labor efficiency have increased steadily, and food is inexpensive and plentiful (Gerber, 1997), for those with money. Achievement of the goal of increased production is undeniable, but it is not sufficient to warrant unqualified praise. The world grows enough food to feed everyone an adequate diet, but not everyone has enough food. It is not a problem confined to developing countries. The county where I live has about 240,000 residents, 40,000 of whom need some assistance each year from the local Food Bank. Agricultural abundance has helped those with effective demand (purchasing power), but the poor are helped secondarily by the generosity of others. Increased production has not done much to decrease the number of homeless or hungry in the developing countries or in the US. Food in the US is cheap, but the cost is still too high for the poor. High production does not automatically lead to equal access. The latter demands changes in public policy, and colleges of agriculture have not been public policy advocates. Busch (1994) suggests that 'increased production is not and should not be the central goal for agricultural research'. Insufficient production is not the food problem. There is enough food produced to feed all Americans an adequate diet, but the hungry among us are not being fed. Feeding the hungry is not part of any college's mission statement.

But American agriculture has also failed in a different way. The agricultural environment is degraded, resources are depleted, rural social systems are fragile or ruined, and, for many reasons, people are no longer connected to the land (Gerber, 1997). The land is regarded by many as something we use, not something to which we belong or to which we owe care. Mission statements applaud success, but failures are not acknowledged. Gerber (1997) argues that colleges of agriculture ought to give up some of their allegiance to what he calls 'academic fundamentalism'. He describes it as a refusal to accept as true any truth that does not originate from 'its own professional standards', by which he means the scientific method. He goes on to argue that farmers also value truth, but it is acquired in a different way. The farmer's goal is not to advance 'universal understanding' but to solve local problems. The knowledge obtained from scientific research 'is sure to be technically sound', but 'farmer's knowledge is more likely to be socially fitting'. Thus, Gerber's (1997) thought brings one back to the nagging question of mission and who the audience is; who is to be served?.

The agricultural research community, including colleges of agriculture, has been slow to accept the challenges and opportunities inherent in the questions that agriculture faces (Logsdon, 1994). As Press and Washburn (2000) claim, colleges have largely aligned themselves with 'those forces in agriculture that defended or denied the negative ecological ramifications of many production practices' (Goodman, 1997) that were developed, perfected or advocated by the colleges.

Colleges of agriculture have survived, and although their original mission has changed, it has not disappeared. The colleges can still be relevant, even in the face of declining farm numbers. The mission has changed, if only because the names have changed; but name changes have not made the college's multiple roles clearer or simpler. The changes (Evans, 1998; see above) have usually expanded, not contracted, the mission. Goodman (1997) sees a continuing role for colleges of agriculture, for two reasons. The first is to ensure a voice for agriculture in the academy, and the second is to provide agricultural training. In Goodman's (1997) view, colleges of agriculture have not had a major role in academic planning because 'they merely colonize the universities they are part of, contributing little to their academic life'. He claims that agricultural colleges should play a leadership role in 'doing interdisciplinary and disciplinary research, offering coordinated curricula', and in contributions to campus-wide undergraduate and graduate curricula. The implication is that these things are not now being done. If this is true, then perhaps agriculture's image in the academy is that we have been colonists. We have accepted the benefits of being part of the academic community, but have not really joined. Agricultural faculty members enjoy being part of the academy but are torn between the obligations that membership carries and the

land grant mission to serve the agricultural community. The real mission is not clear in the minds of the faculty nor in the college's mission statements.

Goodman's (1997) second reason also raises problems. He wants colleges of agriculture to provide 'focused and high-quality professional training'. He advocates the model of medicine, law or engineering. Goodman (1997) suggests 'specialization should occur much later than is typical in many fields' and that agriculture should not 'overemphasize training in skills at the expense of education'. He does not define the difference between training and education, but he clearly favors the latter. His view seems to agree with that of Schuh (1986), who deplored narrowly focused training for particular job skills and knowledge that have a high rate of obsolescence. Goodman (1997) seems to favor, although he does not mention, acquiring a liberal education before specialization.

As mentioned above, agricultural faculty may claim that their research and teaching have not caused the problems that modern agriculture faces (e.g., Berry, 2000; Logsdon, 1994). They may be correct, but that claim risks the accusation that their work has been irrelevant to creation of the modern agricultural system. Similarly, analysis of mission statements may be dismissed because such simple statements really cannot reflect the diversity of what colleges of agriculture do, and the many interests of the faculty. That may be true. If it is true, then one must ask, What is the purpose of the mission statement? How accurate is the mission statement? Does the mission statement reflect what the college does or is? Changing a mission statement won't change mission or the action of faculty quickly, but the mission ought to affect what we do and how we think. Those who write such statements would do well to follow Horton's advice:

> I meant what I said
> and I said what I meant . . .
> an elephant's faithful one hundred percent.
>
> Dr. Seuss (1940)

Conclusions

Agriculture is one of the few, perhaps the most, essential human activity. We live in a post-industrial, information-age society and are moving rapidly toward a society dominated by biology—the bioeconomy. We do not live in a post-agricultural society. Some of our ancestors lived in a pre-agricultural society, but today we all live in societies with an indigenous or external agricultural base, or both. Everything we know and have, indeed, our life, is dependent on that agricultural base (Manning, 2001). People in agriculture know and appreciate that fact, many others do not. However, although it is easy to agree that agriculture is an essential human activity, that does not seem to be an adequate argument to support the claim of the essentiality of the mission, or existence, of colleges of agriculture.

The situation calls for what Taylor (1991) calls 'a complex, many-leveled struggle, intellectual, spiritual, and political in which the debates in the public arena interlink with those in a host of institutional settings'. Public debates are where the issue of agriculture's enframing technology can be seen in concrete form, and where what Taylor (1991) calls the 'demands of authenticity' can be defined. Public debate is where one determines 'the shape of human life and its relation to the cosmos' (Taylor, 1991). In the quest to define the mission, agricultural faculty must not capitulate to intellectual and moral relativism (Pelikan, 1992). That is to say, they must not conclude that a consensus about values is beyond reach, and therefore that a university and its college of agriculture cannot draw on any such consensus to shape the decisions that affect its survival and our lives (Pelikan, 1992).

We know our universities and our colleges of agriculture are in crisis, but that concern does not appear in mission statements that are celebrations of achievement. Saul (1995) claims that universities are 'attempting to ride out the storm by aligning themselves with various corporate interests. This is short-sighted and self-destructive. From the point of view of their obligation to serve society, it is simply irresponsible' (Saul, 1995).

The sensible thing for the university to do would be to turn away from its self-interest in survival to take a leadership role (Saul, 1995). Saul's (1995) challenge was not directed toward colleges of agriculture. If it had been, he might have encouraged a return to, or at least a reconsideration of, the mandated land grant mission (mentioned by 30 colleges). He might ask whether survival or service is the proper goal, the highest value. Returning to the land grant mission might retard the movement toward being the kept university that Press and Washburn (2000) described, and create a focus on what Saul (1995) calls 'the wider obligations of humanism'.

These obligations, and the values that support them, are what colleges of agriculture must consider. Agricultural colleges, similar to other colleges, receive students who have grown up with all day, every day (24/7) access to television, video games on demand, and cell phones at their ear. The right to be instantly and constantly entertained often seems to occupy more of the average undergraduate's thoughts than the right to vote, or to have the vote counted properly (Gitlin, 2000). It is not that students are unaware of their world and its great issues. The concern is that their awareness is talk, gestures and empty rhetoric that fills time but is not troubled by reasoning. There is no expression of values and an absence of moral debate. Their minds are closed (echoes of Bloom, 1997), and the mission statements of colleges of agriculture do not reflect a genuine concern for opening minds or engaging in the agricultural debates about sustainability, soil erosion, pesticide use and misuse, animal treatment and animal rights. 'It is the essence of the university tradition that it defend itself against the encroachment of power' (Carey, 2000). Carey (2000) charges the university with preserving the basis of its

objectivity, inculcating students with 'certain fundamental values: a sense of balance and limitation, a skeptical turn of mind toward all claims of final truth, and a skill in and motivation toward disciplined inquiry'. These explicit goals are not part of the 49 mission statements reviewed for this paper. Carey (2000) emphasizes that 'the most important product of the university is the student'. The educated person is the proper goal. The end of education is for a person to come to an understanding of what it is to be a person. The end is the realization that perpetual self-discovery, perpetual re-shaping is our destiny. The proper role of education is not to serve the academic–industrial complex seen by Press and Washburn (2000), either through job training or research. The proper role is 'to enable citizens to live lives that are economically, politically, socially, and culturally responsible' (Berry, 2001). That kind of education will teach, and students will learn, that creation of a just society is the best goal. A just society is not an explicit goal in the mission statement of any college of agriculture.

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Interactions Between Agroecosystems and Rural Communities. Edited by Cornelia Flora. 2001. CRC Press, Boca Raton, FL. xvi+273 p. US$79.95, ISBN 0-8493-0917-4, hardcover.

Interactions between Agroecosystems and Rural Communities makes a strong case for the mutual interdependence of ecosystems, social systems and human action. It also makes strong cases for considering these jointly for more sustainable futures and for developing locally accepted, workable and socially equitable solutions to problems. Stated differently, the 17 chapters written by authors with a wide variety of both perspectives and experiences demonstrate that the particulars of society and ecology matter greatly in how—even whether—agricultural and agroforestry production systems in a locality can support a human population over the long haul.

Because many persons interested in sustainability may see these interrelationships and interdependencies to be self-evident—I certainly began my reading with such a notion—why bother to read the book? Let me offer three reasons: the various chapters reveal that not all attempts to solve environmental and social problems include considerations of these social and ecological interrelationships. They also show that applying such considerations in practice is challenging, complicated and time-consuming. Finally, they demonstrate that successful strategies for applying such considerations vary greatly with the particulars of local situations.

In the first chapter, Cornelia Flora introduces the chapters of the book and in the second chapter she outlines the theoretical perspective that presumably served as the basis for soliciting and selecting these chapters. Those already familiar with her work will likely find few surprises here. From her perspective, agroecosystems and communities are embedded in larger ecosystems and societies. Anchoring one part of the theory are three interrelated, multifaceted and, in some ways, competing institutional spheres: market, state and civil society. Markets are comprised of firms and sets of social arrangements involved with exchanging goods and services for profit. States are governments, including the apparatuses of the legislative, administrative and judicial branches, which both set many of the rules for markets and putatively provide for public welfare. Civil society is the collectivity of informal and formal groups; each group composed of members who act jointly to define and maintain values and interests, to imagine desired futures, and then advance these as 'the common good' in dealings with markets and states. Each of these institutional spheres is characterized by contestation from within because of differing, often incompatible, interests involved and because of differing conceptions of 'the common good'. These spheres are also linked because, as individuals, people participate in all three spheres. In addition, distinguishable versions of these institutions are manifested at all levels from the local to the global, leading to additional potential for conflicts. Out of the institutional maelstrom emerges tendencies at particular times and places for one institutional sphere to dominate the others, and Flora sees domination by either states or markets as portending problems for agroecosystems and rural communities. Moreover, implied throughout the book is that domination by institutions at higher levels, e.g., national or global, likely also leads to adverse consequences for local communities and their agroecosystems.

The other theoretical anchor is the conceptualization of four forms of capital: human capital is people's 'skills, knowledge, and abilities' (p. 10). Social capital is a community's 'communication...[,] networks...[,] initiative and responsibility' (p. 10). Natural capital includes soil, plants and animals. And financial/built capital includes money and infrastructure. Each of these capitals has the potential to generate new resources for development, but sustainability requires that it be used in ways that do not deplete its stock in the long run. Similarly, using any kind of capital in ways that deplete the stocks of other kinds of capital undermines the vitality and sustainability of a community. Use of particular forms of capital at any particular time is shaped by the contemporary configuration of the institutional spheres, e.g., if markets dominate the institutional sphere, pursuit of profit by those with power may lead to degraded agroecosystems and undermined rural communities.

From the vantage point provided by this theoretical framework, what are the conditions that Flora sees as fostering sustainable agroecosystems and rural communities? One key is the institutional balance described above, because it provides a context in which sustainability is possible. Another key is that the different kinds of capital need to be used in appropriate balance as 'resources to create, maintain, and improve local livelihoods' (p. 11) through diverse activities that enable community members to achieve a degree of local self-reliance, to weather changing economic conditions and to adapt to changing markets. Human and social capitals are seen to be the starting points for efforts to improve the sustainability of communities and agroecosystems. Still another key is social equity, which refers to access to opportunities for individuals and communities to participate and take initiative as producers and consumers in the economy, as citizens in governance, and as participants in civil society. Social equity is important for the development of human and social capitals which, in turn, helps to promote institutional balance.

Chapters 3 through 8 illustrate the challenges to agroecosystems, economies, and community faced by

rural communities in a wide range of contexts. John Soluri writes about how a Honduran community was impacted when outsider-controlled, large-scale commercial production of one variety of banana was introduced, became the dominant economic activity, and then subsequently collapsed due to a disease. This illustrates how an agroecosystem and a community, which are always changing, can be radically remade by outside forces and then be remade again upon abandonment of the locality as a site of production. Chris Mayda presents an account of the rise of large-scale, vertically integrated pork production in two counties in Oklahoma. The experience in the two counties was quite different, due to different approaches of the corporations involved and different community and ecosystem conditions in the counties, suggesting that regulatory approaches should be based on the particularities of local situations rather than uniform rules. Daniel Klooster describes how social inequity in a Mexican *ejido* community in a forested area undermined community and led community members to poach timber unsustainably on community lands. This contrasts unfavorably with communities that were otherwise similar, but with greater social equity. Magdalena Barros Nock illuminates the problems faced by farmers in two small Mexican *ejidos* that undertook producing and packing fruits and vegetables for export as a development strategy. Both were ultimately unsustainable for business, social and ecological reasons. Felix Herzog and Anja Oetmann write of a European extensive agroforestry system (*streuobst*) for producing fruit that persists in spite of being somewhat uncompetitive with the intensively managed orchards favored by public policy. The ecological diversity promoted by *streuobst*, the local fruit varieties it preserves, and its importance to local cultural identities has led to cooperation between agriculture and environmental interests and has motivated environmental organizations to defend the system through creating specialty marketing systems and supporting protective legislation. Monica Bendini portrays the situation of the nomadic sheep- and goat-raising peasant communities in Argentina. Their existence has become threatened because increasing land privatization has left them relegated to marginal lands, and others perceive of them as being the source of ecological degradation. Despite this, their communities remain strong and they resist being defined as a problem.

Chapters 9 through 15 discuss the experiences and conclusions from a variety of fascinating interventions aimed at changing communities. Consistent with the framework laid out by Flora in the introductory chapters, all are valuable in offering insights and possible approaches for persons interested in affecting change in agroecosystems and communities. Cornelia Flora, Gregory McIsaac, Stephen Gasteyer and Margaret Kroma recount and analyze a case of a group of entrepreneurial farmers in Illinois who built alternative markets and took risks in shifting from producing undifferentiated bulk commodities to producing commodities for specialty markets. In my mind, this is one of most important chapters because of the thoughtful analysis of the resource flow implications of this shift, an approach that should be emulated widely. Clive Lightfoot and 12 colleagues provide a highly informative discussion about the application of a complex learning framework approach to participatory agroecosystem management in several African and South American countries. The approach is too complex to summarize succinctly, but it includes analysis of organizational contexts, visioning on the part of farmers, a series of learning instrument tables, and assessing the results of attempts at change. This approach looks very promising; however, the authors warn that obtaining the resources to implement it may be difficult. Lorna Butler and Richard Carkner use a foodshed analysis to address the lack of commonly understood relationships among agriculture, communities and ecosystems in North America. They examine three case studies of agricultural enterprises where operators both strive for sustainability and connect directly with the citizens who consume their produce. From these cases Butler and Carkner discern seven principles for success in promoting sustainability through building new relationships with citizens. Wayne Monsen describes a 'rural community leadership' approach used to bring together farmers and representative others in a Minnesota community with a lake threatened by pollution. Through a series of workshops, participants were guided to develop a shared vision for their community, identify principles for decisions, and arrive at priority issues and, through the process, build social capital and become empowered. Lita Rule, Marcella Szymanski and Joe Coletti recount an interdisciplinary, multistep land-use planning process conducted with the Winnebago Tribe of Nebraska. The process involved creating objectives based on the values, needs and concerns of the Winnebago people, developing a set of land-use alternatives, examining the implications of and ranking each alternative. Marie de Lourdes Barón and David Barkin report on a creative adaptation of traditional small-scale hog raising among indigenous communities in Mexico to produce lower-fat pork by feeding unmarketable avocados and then to market that pork as a specialty product. Though still in the experimental stage, this promises to improve the economic situation of the local people while retaining local control over this economic activity. Daniel Montjoy emphasizes the importance of distinguishing subcommunities among farmers in an area of California where strawberry farmers of Anglo, Japanese and Mexican descent are differentiated, not only by culture, but also by specialized knowledge, network participation and access to resources. These differences lead to different management styles, which, in turn, require different outreach and education strategies, different technologies and different regulatory approaches to satisfactorily address community ecological concerns.

The final two chapters are speculative; however, such visioning is important because it stimulates thinking, not only about solutions to problems of agroecology and

community development, but also to solutions to conflicts at the rural–urban interface, something that is becoming more common with increasing urban sprawl. Michele Schoenenberger, Gary Bentrup and Charles Francis advocate multiple-use 'ecobelts' of trees and other vegetation for improving water quality, separating agriculture and nonfarm development, provide wildlife habitat, create recreational opportunities and many other reasons. In the afterword, Charles Francis generates a heartwarming futuristic scenario for a genuinely ecological community that is sensitive to its ecosystem and adapted to it.

Taken as a whole, a major strength of *Interactions between Agroecosystems and Rural Communities* is its largely consistent theoretical framework for examining the interrelationships between communities and ecosystems and for promoting forms of development that serve both the needs of community members and promote sustainability. Another strength is the wide range of cases that show the relevance of the theory in different situations. Still another strength is an index, a feature not always found in edited books.

My criticisms are minor. 'Missing' is a chapter that situates the perspective taken in this book within the context of the different theoretical approaches to understanding and promoting development. The book's theme relates substantially to the concept of the multifunctionality of agriculture, which is currently in vogue, yet I recall only one mention of the term. The reference style is not consistent across all the chapters.

I recommend this book to scholars and practitioners. It also seems suitable for use in graduate and advanced undergraduate classes. The chapters are well written and in a style that is quite accessible; however, for uninitiated readers certain chapters might be a bit too abbreviated to convey adequately the complexity of the ideas and concepts behind them. Notable examples are Flora's brief theoretical introduction in Chapter 2 and Lightfoot et al.'s learning approach in Chapter 10. Although expecting a single book to do everything is unreasonable, I point this out only to note that the book will serve more as an important orienting guide than a 'how-to' handbook.

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